HDL-CR-77-787-1

AD A041145

HANDBOOK OF FLUIDIC SENSORS

MAY 1977

Prepared by

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Under Contract

DAAG39-76-M-6787

U.S. Army Materiel Development and Readiness Command
HARRY DIAMOND LABORATORIES
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HDL **REPORT DOCUMENTATION PAGE**	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: CR-77-787-1	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE *(and Subtitle)*: HANDBOOK OF FLUIDIC SENSORS	5. TYPE OF REPORT & PERIOD COVERED: Final Report.
6. PERFORMING ORG. REPORT NUMBER: TR-120	
7. AUTHOR(s): Leonard M. Sieracki	8. CONTRACT OR GRANT NUMBER(s): DAAG39-76-M-6787
9. PERFORMING ORGANIZATION NAME AND ADDRESS: LORELEI Corporation, 615 South Frederick Avenue, Gaithersburg, Maryland 20760	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Program Element: 6.21.14.A
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Materiel Development and Readiness Command, Alexandria, VA 22444	12. REPORT DATE: May 1977
	13. NUMBER OF PAGES: 219
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*: Harry Diamond Laboratories, 2800 Powder Mill Road, Adelphi, MD 20783 (12) 191 p.	15. SECURITY CLASS. *(of this report)*: Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

DRCMS Code: 612114.H730011
HDL Project No.: 304 734

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Fluidics, Sensors, Proximity Sensors, Rate Gyros, Accelerometers, Flow Meters, Densitometers, Temperature Sensors, Concentration Sensors, Pressure Ratio Sensors.

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The operational and physical characteristics of fluidic sensors are presented. Emphasis has been placed on those devices that are commercially available. The format is arranged so as to provide system designers with detailed data necessary to determine whether a particular device can be employed in a given system. For each sensor, manufacturer, data source, and point of contact are also listed.

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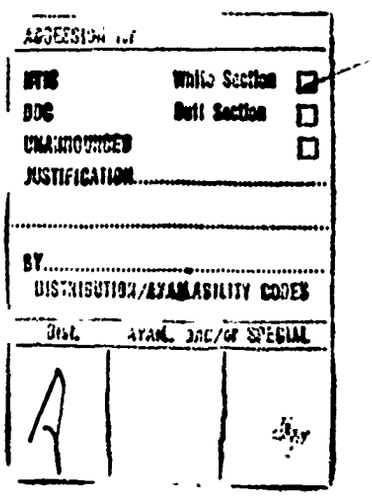
PREFACE

Presented herein is a survey of fluidic/flueric sensors that are commercially available or have reached an advanced development stage. Please note that neither the U.S. Government nor LORELEI Corporation advocates the use of any of the products described in this document. Rather, the manual is a factual listing of the operational and physical characteristics of representative fluidic components, compiled from data received from sources that responded to LORELEI queries.

This work was performed under the auspices of the Joint Logistic Commanders' Joint Technical Coordinating Group on Fluidics (JTCG-Fluidics). The effort was cosponsored by the Harry Diamond Laboratories and Naval Air Systems Command.

LORELEI Corporation wishes to thank Mr. Richard Gottron and Mr. James Joyce of the HARRY DIAMOND LABORATORIES for their assistance and direction during the preparation of this manual. We also wish to thank all those manufacturers and government personnel who took the time to respond to our detailed questionnaire.



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1. INTRODUCTION

1.1 General

Since the early 1960's, considerable effort has been expended by many investigators to quantify the operating characteristics of fluidic/flueric systems. However, despite extensive research, only a relatively small number of different types of components have been developed by commercial manufacturers. In general, the types of fluidic components commercially available fall into four main categories:

- Sensors
- Interface Devices
- Logic Devices
- Control Devices

These areas represent a broad spectrum of applicability for fluidic/flueric components; however, this report is pertinent only to sensors.

1.2 Statement of Problem

In broad terms it is convenient to define a sensor as any device that receives an input signal and provides a proportional output signal. This can be easily seen in the diagram presented in Figure 1.1. The input variable may be a motion (i.e., linear and angular displacement, velocity, or acceleration) or a characteristic of the medium (i.e., pressure, temperature, humidity, gas concentration, flow rate, etc.) Regardless of the input, the output of a fluidic sensor is typically a pressure or flow signal which may be analog, digital, or digital proportional (i.e., oscillating). This wide variation of both input and output parameters leads to a rather complex array of components especially since some can perform more than one sensing function.

As a further complication, sensors in general and fluidic sensors in particular are most always "size" dependent. Therefore, the geometric characteristics of a sensor designed to measure a specific parameter in a fluid

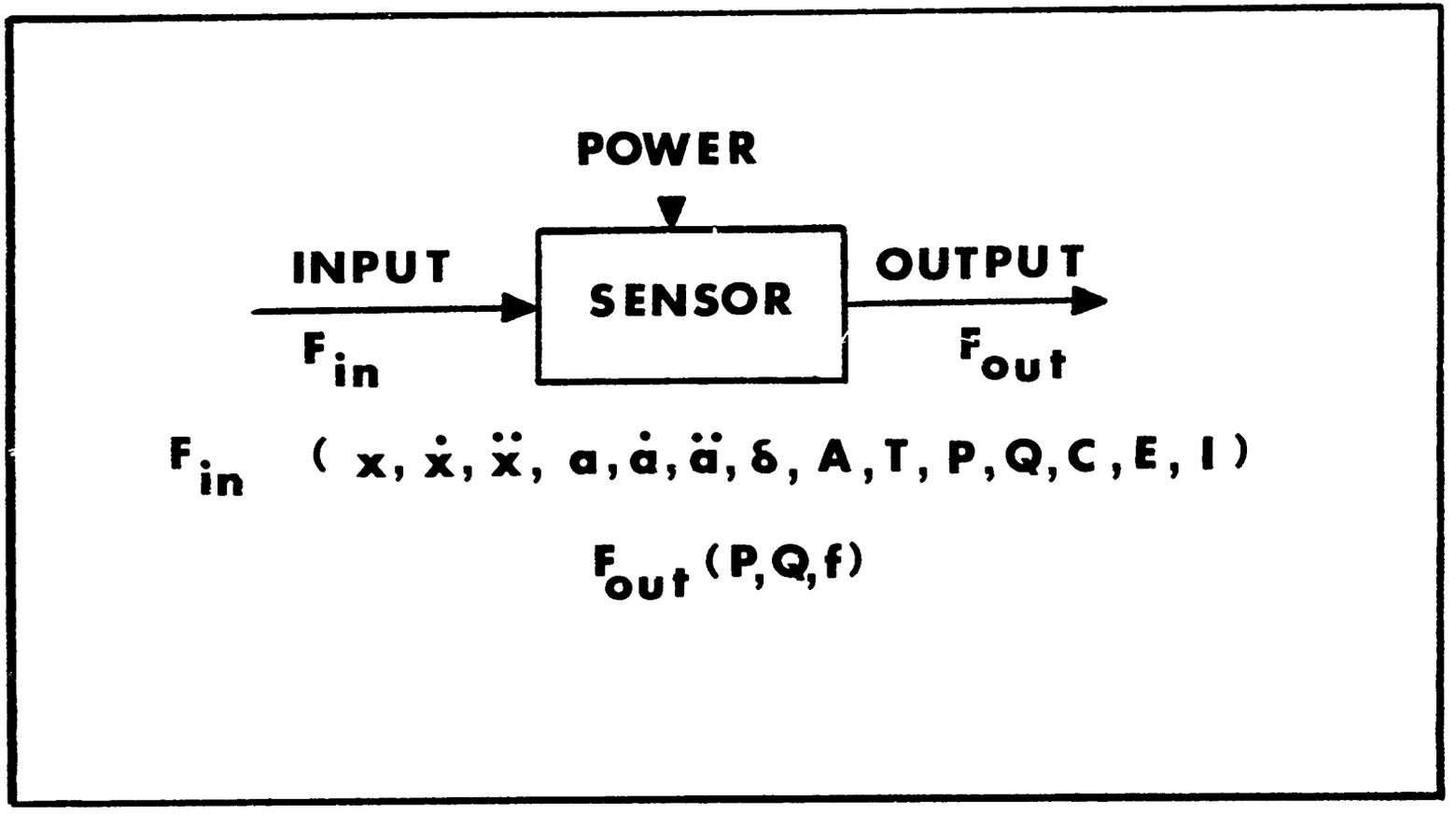

FIGURE 1.1 BLOCK DIAGRAM OF FLUIDIC SENSORS

medium flowing at a rate of 1 scfm, may require complete redesign in order to utilize the same sensor in a medium flowing at a rate of 10 scfm. Thus, one of the common problems facing system designers is that data cannot always be directly extrapolated from a single laboratory test, to a wide range of other situations.

1.3 Objective

Although fluidics has been recognized for over a decade as offering promise in the areas of sensing and classification of the sensed function, the industry in general has experienced difficulty in universally applying the technology. As mentioned, the prime reason for this is that a component designed for a specific application may require complete redesign for a similar application which requires a much larger or much smaller sensing element. One common solution employed by major manufacturers is to no longer offer individual components, but only offer a tailored design for a total system which would employ their unique sensing and logic elements. To some degree, this perpetuates the problem of fluidic system development. Conversely, many commercial manufacturers who provide components for general use by the industry typically do not provide enough system design information to allow their components to be used easily by non-fluidics oriented personnel.

The objective of this manual, therefore, is to provide to system designers (both fluidic and non-fluidic oriented) a basic compendium of the state-of-the-art technology of fluidic sensing elements. The manual provides detailed information (where possible) on the operating characteristics of the sensors, i.e., input parameters, output parameters, impedence matching requirements, etc. The ultimate goal of this manual, therefore, is not to provide the average individual the necessary background to design fluidic sensors, but rather to supply the system designer with enough information so that he can utilize state-of-the-art fluidic sensors in his present system as a replacement for other sensors which may be purely mechanical or electronic in nature.

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1.4 Overview

The material presented within this manual is pertinent primarily to those sensors that are commercially available either as off-the-shelf or special order components. Also delineated to a lesser degree are sensors currently under development or being researched by government R&D labs, by industry, or by universities. Most detailed information has been obtained on commercial sensors, and it is upon these parameters that the system designer should base his system design. However, in the event the function cannot be performed adequately by commercial fluidic components, and/or the particular system for which the element is being considered is in the R&D stage, then obviously the system designer should consult the material detailing sensors currently under development.

The section is subdivided into specific areas containing detailed information on each sensor. Information was acquired by an extensive literature survey, which commenced with a questionnaire sent to approximately 500 organizations (manufacturers, government agencies, and universities) located both within and outside the United States. A copy of the questionnaire is included as Appendix A. Approximately 35% of the contacts responded in part to the questionnaire. Their responses consisted of filling out the questionnaire and providing the supplemental information or simply mailing the marketing information they commonly supply in advertising literature. As a result, the material presented in this report is not consistent for each sensor. However, a point of contact is indicated in most cases to allow the reader to obtain other detailed information directly from the source. It should be noted that the emphasis herein is placed primarily upon substantiated data, and laboratory tests of prototypes or research devices are labeled as such.

2. COMMERCIALLY AVAILABLE SENSORS

2.1 General

Fluidic sensors, in general, can be categorized several ways. For convenience, however, they are usually classified either according to their function or according to their design. The latter designation may be confusing. For example, a vortex sensor may be used to detect angular rate, temperature, or gas concentration. Therefore, to eliminate confusion in the following discussion, the categorization is first made according to the function of the sensor, and then according to the type of sensor within each of these categories. Breakdowns according to function are:

- Proximity Sensors
- Angular Rate Sensors
- Accelerometers
- Temperature Sensors
- Concentration Sensors
- Miscellaneous Sensors

As stated in the Introduction of this manual, a discussion of each generic type of sensor and of each particular type of sensor has been prepared in accordance with the information received from the questionnaires sent to the various sources. As such, the presentation of pertinent material varies slightly from sensor to sensor, depending upon the responses received. The format for each sensor investigated remains consistent throughout the report. Note that the term (NA) is used to indicate items which are not applicable to a particular sensor. Where data were not provided, a (U) for "unspecified" is utilized. Logic symbols are those used by each manufacturer.

2.2 Proximity Sensors

Proximity sensors are devices which provide either an analog or digital output signal that is dependent upon the juxtaposition of an object passing by the sensor. The two basic types of proximity sensors are non-

contact and contact. With a non-contact sensor, a jet stream is usually aimed across a gap. When that stream is interrupted by an object entering the gap, a resultant change in output pressure and flow occurs. A diagram of both variations of the basic proximity sensor theme is shown in Figure 2.1. In Figure 2.1a, a jet stream impinges against the moving object, causing an output signal in the form of a back pressure change. In Figure 2.1b, an object would pass by the flow port, labeled "C." Depending upon the proximity of C to the sensor, either full or partial flow differentiation will take place between D_1 and D_2. If the flow switches completely from D_1 to D_2, the device is known as a digital (on-off) sensor. If the flow rate is proportional between D_1 and D_2 (to the distance of the object from C), then the device is known as a proportional sensor. It should be noted that a pushbutton (where a finger can be used as the flapper of the valve as shown in Figure 2.1a) is the simplest type of proximity sensor. Variations of this basic element are referred to by manufacturers as "key" or "back pressure switches." Detailed information on all of the various types of proximity sensors follows.

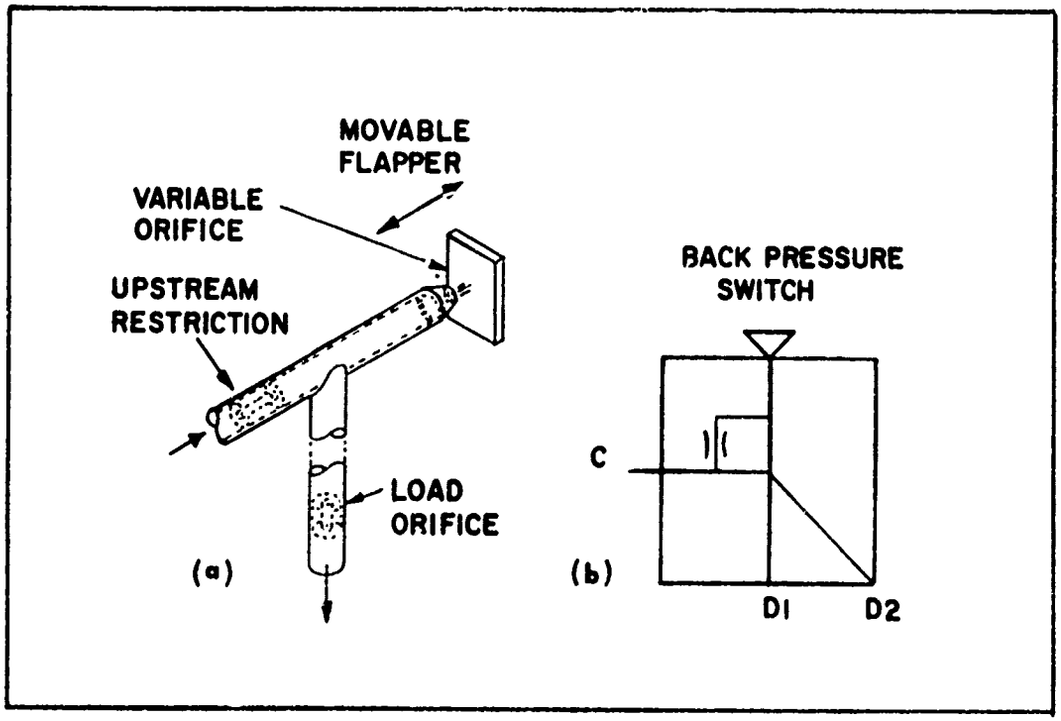


FIGURE 2.1 BASIC PROXIMITY SENSOR OPERATION

2.2.1 Cone-Jet Proximity Sensor

The cone-jet proximity sensor employs an annular nozzle connected to a supply port as shown in Figure 2.2. The annular sensing nozzle surrounds an output port and, if not interrupted, the air flow forms a conical jet, thus creating a negative pressure at the output. When an object passes through the cone region of the jet, the normal sub-atmospheric region becomes one of positive pressure due to the supply jet being deflected from the intruding object into the low pressure region. The result is a high pressure output signal, the magnitude of which is inversely proportional to the spacing between the object and the annular nozzle. Manufacturers claim that there are no "overtravel" problems such as are encountered with conventional limit switches and valves, and the device is ideal for conditions where physical contact could cause damage to the parts. Flat or curved objects up to .25 in from the nozzle can be sensed. It should be noted that this type of proximity sensor requires at least a .25-in-square surface for positive activation and, therefore, does not lend itself to sensing wires or other small objects.

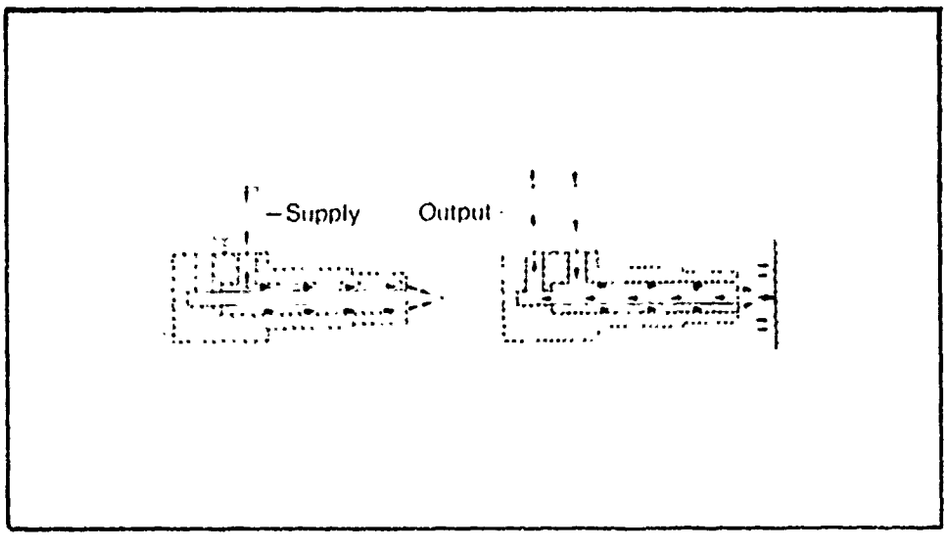


FIGURE 2.2 CONE JET-PROXIMITY SENSOR

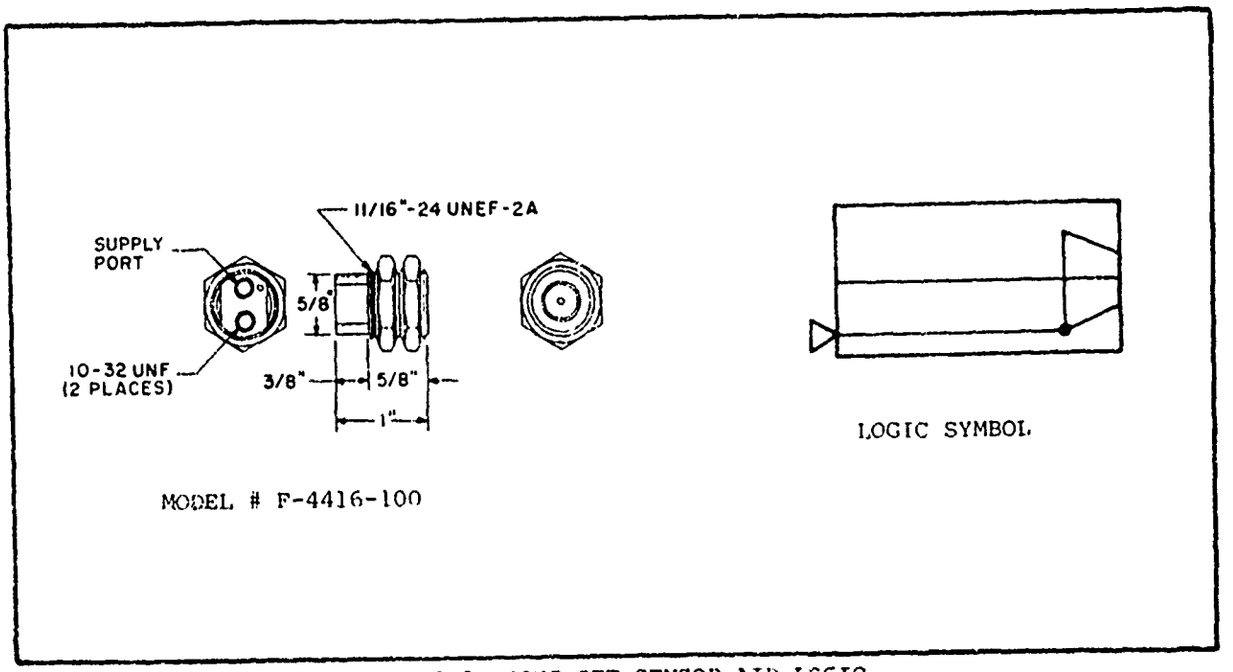


FIGURE 2.3 CONE JET SENSOR-AIR LOGIC

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet, approximated via 3 equally spaced nozzles

DATA SOURCE: Air Logic Brochure #8350 Part No. F-4416-100

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 0 to 180°F PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Air Logic Div.
Fred Knapp Engraving Co., Inc.
5102 Douglas Ave.,
Racine, Wisc. 53402

POINT OF CONTACT: Mr. Donald Kaske (414) 639-3941

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $14.90 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U — TIME RESPONSE: 2 ms

SUPPLY:	PRESSURE-Minimum:	10 psig	Maximum:	10 psig
	FLOW-Minimum:	0.36 scfm	Maximum:	0.36 scfm
	POWER-Minimum:	U	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	See Figure 2.4	Maximum:	
	FLOW-Minimum:		Maximum:	
	POWER-Minimum:		Maximum:	
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: Output to drive AIR LOGIC Fluidic elements

SCALING ABILITY: NA

LINEARITY: RANGE: NA — ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.20" — MINIMUM OBJECT SIZE: 0.5" Flat 0.25" Radius

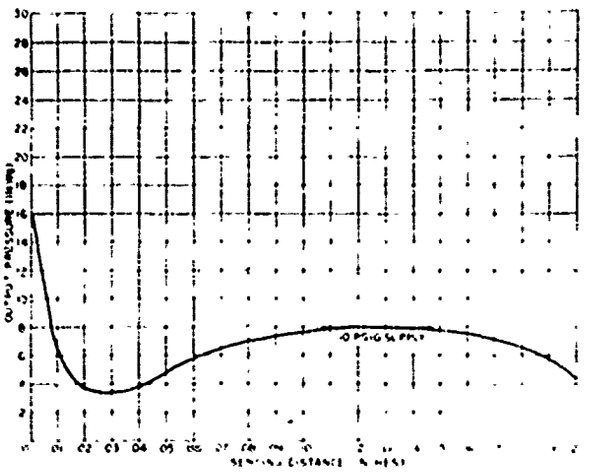
HYSTERESIS: U — GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA — EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



Output Pressure vs Sensing Distance

FIGURE 2.4 AVAILABLE DATA-CONE JET SENSOR-AIR LOGIC

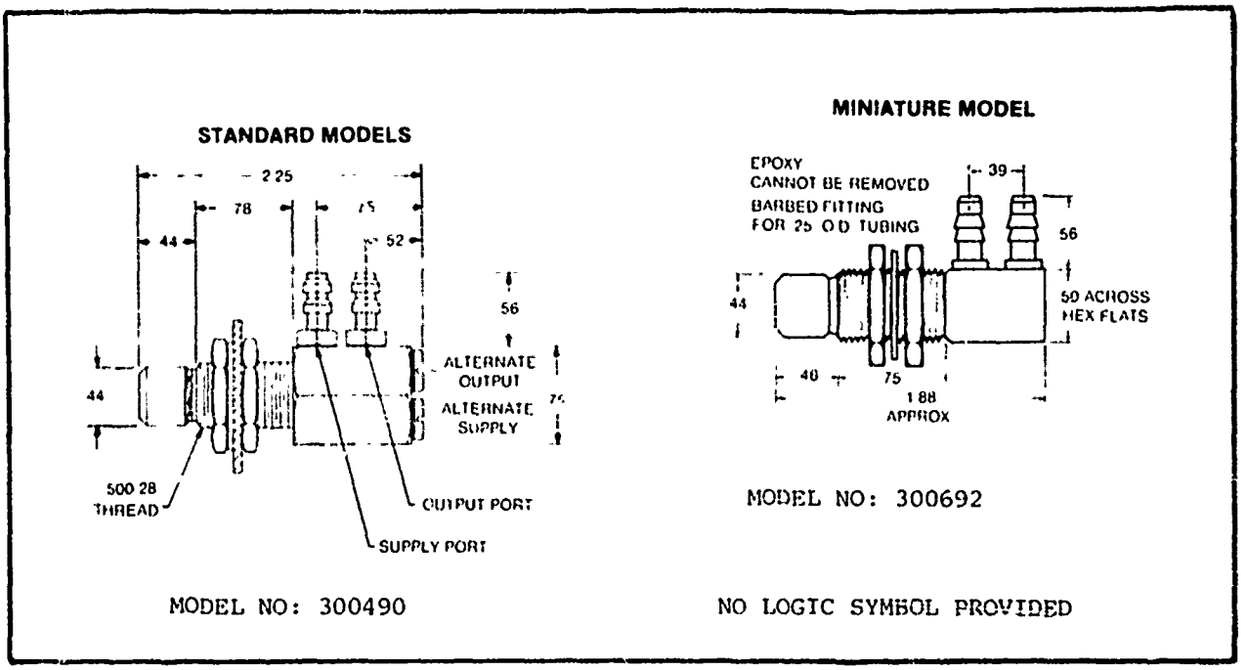


FIGURE 2.5 CONE JET SENSOR-AIRMATIC/BECKETT-HARCUM

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Airmatic/Beckett-Harcum Brochure AB-450

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -50 to 180°F PRESSURE: > 35 psig

POWER SUPPLY FILTRATION: 40 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Airmatic/Beckett-Harcum
185 Park Drive
Wilmington, Ohio 45177

POINT OF CONTACT: Mr. Cliff Howard (513) 382-1691

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U — TIME RESPONSE: 1 ms

SUPPLY:	PRESSURE-Minimum:	2 psig	Maximum:	35 psig
	FLOW-Minimum:	0.25 scfm	Maximum:	2.0 scfm
	POWER-Minimum:	1.63 w	Maximum:	228 w
OUTPUT:	PRESSURE-Minimum:	See Figure 2.6	Maximum:	
	FLOW-Minimum:		Maximum:	
	POWER-Minimum:		Maximum:	

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA — ACCURACY: 0.005 inch repeatability

OBJECT SENSING RANGE: 0" to 0.2" — MINIMUM OBJECT SIZE: .0625" wire

HYSTERESIS: U — GAIN: NA

OUTPUT SIGNAL: Propertional pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA — EXPECTED LIFE: Unlimited

MTBF: U MCBF: U MTTR: U

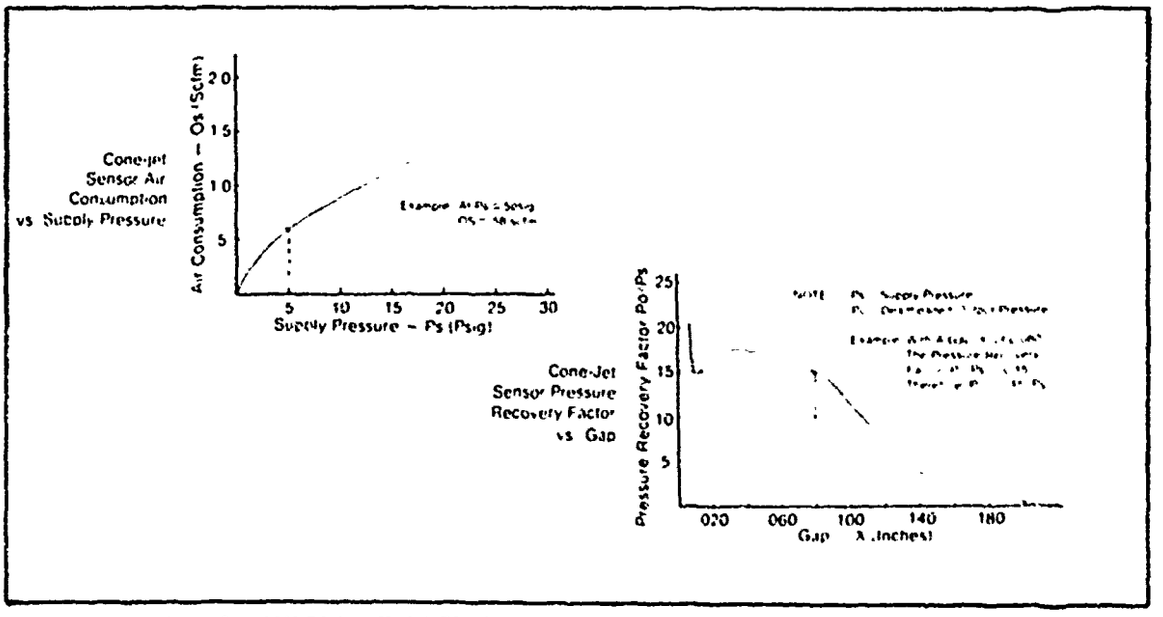


FIGURE 2.6 AVAILABLE DATA-CONE JET SENSOR-AIRMATIC/BECKETT-HARCUM

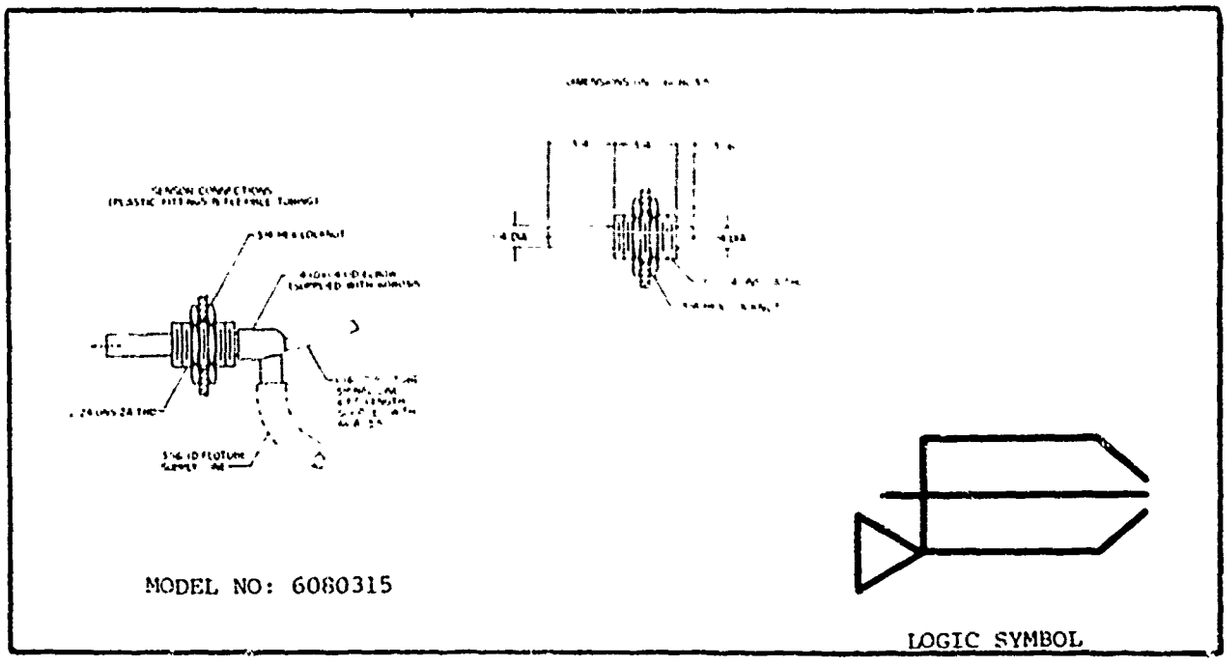


FIGURE 2.7 CONE JET SENSOR-ASCO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: ASCO Brochure no. F9028: Part # 6080315

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Automatic Switch Company
50-56 Hanover Road
Florham Park, New Jersey 07932

POINT OF CONTACT: Mr. Edward E. Dorsey (201) 966-2000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $25.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 1 ms

SUPPLY: PRESSURE- 1 to 10 psig FLOW- 0.5 to 2.5 scfm

OUTPUT: PRESSURE- See Figure 2.8

IMPEDANCE: U

SCALING ABILITY: None

LINEARITY: RANGE: See Figure 2.8 ACCURACY: U

OBJECT SENSING RANGE: 0 to 0.13" MINIMUM OBJECT SIZE: (*)

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Proportioral Pressure

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

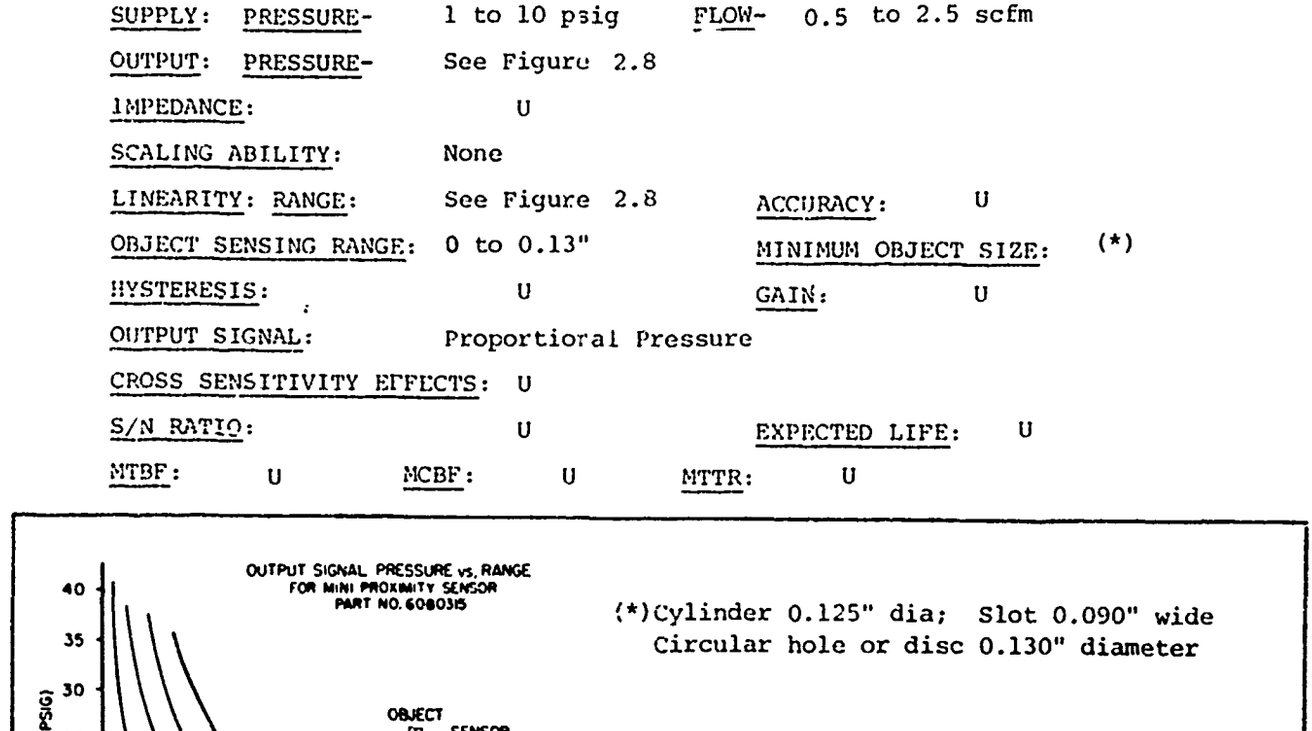
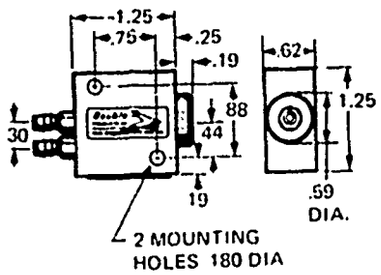
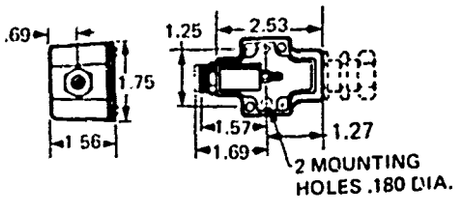


FIGURE 2.8 AVAILABLE DATA-CONE JET SENSOR-ASCO



MODEL NO: FPD-P1-10A1



MODEL NO: FPD-P1-13A1

NO LOGIC SYMBOL PROVIDED

FIGURE 2.9 CONE JET SENSOR-BROWN AND SHARPE

GENERAL INFORMATION

TYPE OF SENSOR: Proximity
MOVING PARTS: None
PRINCIPLE OF OPERATION: Cone Jet
DATA SOURCE: Brown & Sharpe Brochure, P-14123
PRIMARY FLUID: Air
INTERFACE: Air-Air
READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U
PRESSURE: U
POWER SUPPLY FILTRATION: U
EFFECT ON MEASURED QUANTITY: None
SENSITIVITY TO:
SHOCK: None
NOISE: None
ACCELERATION: None
VIBRATION: None
REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Brown & Sharpe Mfg. Inc.
Double A Products
714 East Duncan Street
Manchester, Michigan 48158
POINT OF CONTACT: (313) 428-8311
PRODUCT AVAILABILITY: Off-the-Shelf
COST: U

NOTE: Miniaturized version is Model No. FPD-D3N-11A1, but no data are given.

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 500 Hz

TIME RESPONSE: 1 ms

SUPPLY: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: Recommends use of Amplifier FPA-2N-10A1

SCALING ABILITY: NA

LINEARITY: RANGE: NA

ACCURACY: 0.005 inch

OBJECT SENSING RANGE: 0" to 0.15"

MINIMUM OBJECT SIZE: .25"Flat,.50" cylinder
1.1" Sphere

HYSTERESIS: U

GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 160 Hz TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: 1.5 psi Maximum: 3.5 psi

FLOW-Minimum: 0.3 scfm, Model RFL-2 0.5 scfm, Model RFL-4, RML-5

0.6 scfm, Model RFL-6 1.7 scfm, Model RFL-15

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0.90" to .620"* MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN:

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Depending upon Model

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: <5ms

SUPPLY: PRESSURE- Nominal: 3 psig

OUTPUT: PRESSURE- See Figure 2.11

IMPEDANCE: Recommend Useage of B&S Amplifier FPA-1P-10A1 or FPA-9A-10A1

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCUPACY: U

OBJECT SENSING RANGE: 0.1" to 0.4" MINIMUM OBJECT SIZE: U

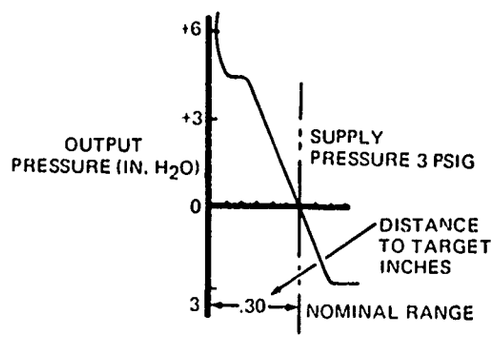
HYSTERESIS: U GAIN: 0.83 psig/inch

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



NOTE: With a 3 psi supply pressure, the sensitivity is .83 psi/inch around the nominal sensing range.

USE PRESSURE AMPLIFIER FPA-1P-10A1 OR FPA-9A-10A1

FIGURE 2.11 AVAILABLE DATA-CONE JET SENSOR-BROWN AND SHARPE

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: <5ms

SUPPLY: PRESSURE- Nominal: 3 psig

OUTPUT: PRESSURE- See Figure 2.11

IMPEDANCE: Recommend Useage of B&S Amplifier FPA-1P-10A1 or FPA-9A-10A1

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCUPACY: U

OBJECT SENSING RANGE: 0.1" to 0.4" MINIMUM OBJECT SIZE: U

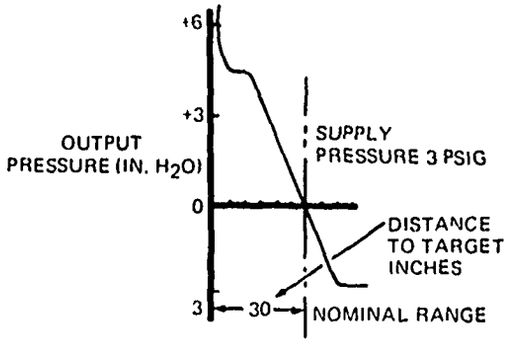
HYSTERESIS: U GAIN: 0.83 psig/inch

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

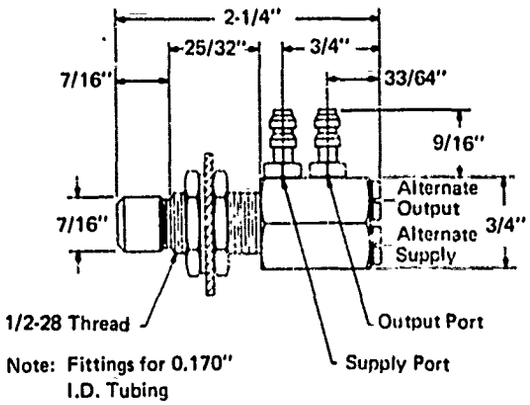
MTBF: U MCBF: U MTTR: U



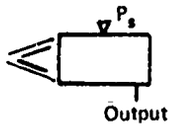
NOTE: With a 3 psi supply pressure, the sensitivity is .83 psi/inch around the nominal sensing range.

USE PRESSURE AMPLIFIER FPA-1P-10A1 OR FPA-9A-10A1

FIGURE 2.11 AVAILABLE DATA-CONE JET SENSOR-BROWN AND SHARPE



MODEL NO: 191593



LOGIC SYMBOL

FIGURE 2.12 CONE JET SENSOR-CORNING

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Corning Fluidic Products Brochure: Part # 191593

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Corning Glass Works
Fluidic Products Department
Corning, N.Y. 14830

POINT OF CONTACT: William T. Greenfield Jr. (607) 974-8147

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $23.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION:

FREQUENCY RESPONSE: U

TIME RESPONSE: *0.030sec rise, fall time with 0.1" gap

SUPPLY: PRESSURE- See Figure 2.13

OUTPUT: PRESSURE- See Figure 2.13

IMPEDANCE: Fanout is 3 CORNING FICM components

SCALING ABILITY: NA

LINEARITY: RANGE: NA

ACCURACY: U

OBJECT SENSING RANGE: 0 to 0.625"

MINIMUM OBJECT SIZE: .25"x.25"

HYSTERESIS: .004"-103"

GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Response tests are performed using 5 psig supply pressure and a 10 foot length of 0.17 in.ID tubing between sensor and switch. A large, flat object is rapidly moved into/out of the sensing field in a direction perpendicular to the flow axis of the sensor. Response is measured at the output of the switch.

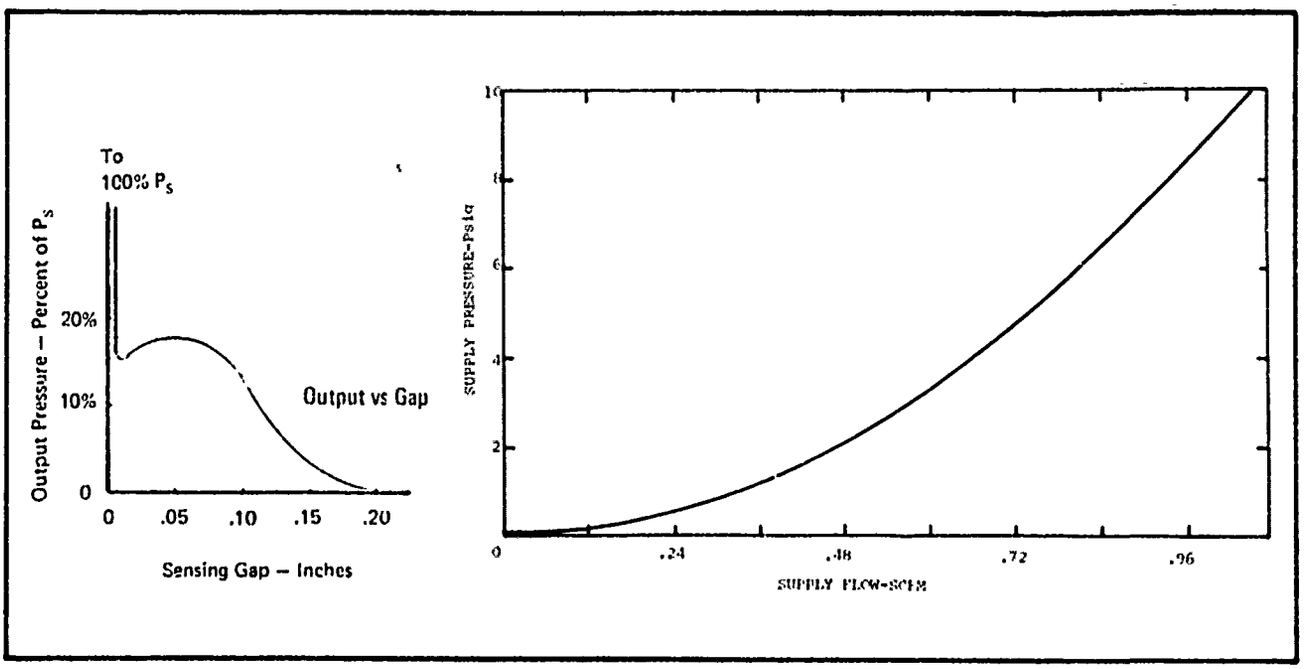


FIGURE 2.13 AVAILABLE DATA-CONE JET SENSOR-CORNING

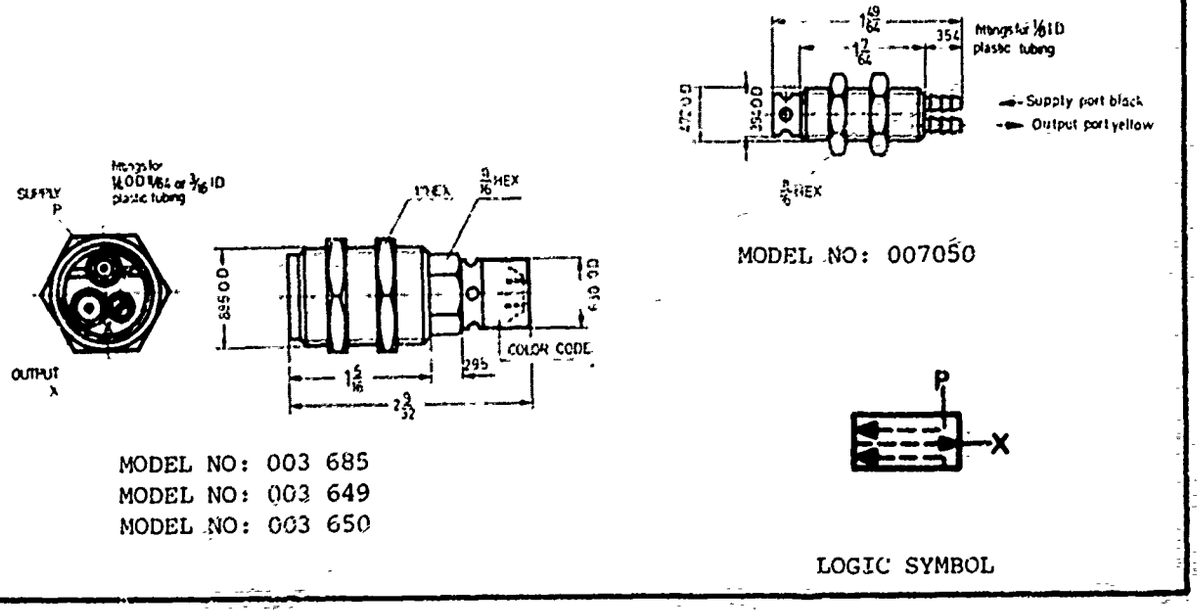


FIGURE 2.14 CONE JET SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Festo Brochure No 1000-2

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: 25 micron dry air

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive
E. Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $21.50 each Model 003685, 003649, 003650

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.15

OUTPUT: PRESSURE- See Figure 2.15

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA

ACCURACY: See Figure 2.15

OBJECT SENSING RANGE: See Figure 2.15

MINIMUM OBJECT SIZE: See Figure 2.15

HYSTERESIS: U

GAIN: NA

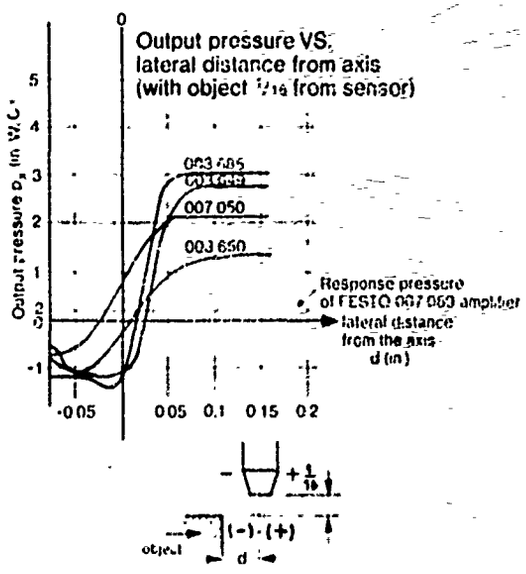
OUTPUT SIGNAL: Pressure rise with object present

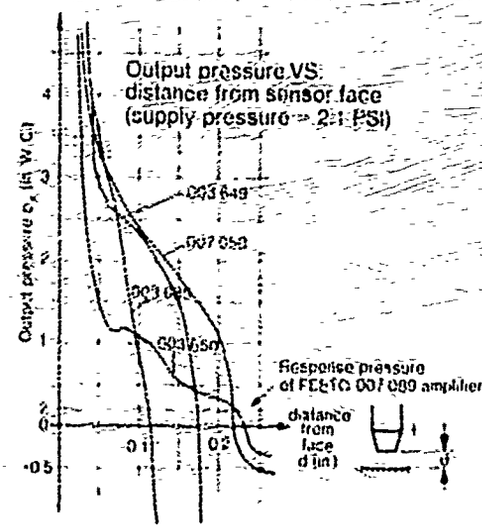
CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U





Type	007 050	003 685	003 649	003 650
Supply pressure (PSI)		1.5 to 7		
Output pressure (in.WC)		.2 (see graph)		
Air consumption at 3 PSI input pressure (SCFM)	.46	.23	.46	.56
Sensing accuracy (in.)	.008	.004	.004	.008
Distance between sensor and object (in.)	1/32	1/8	5/32	1/4

Type	007 050	003 685	003 649	003 650
Identification color	-	red	yellow	white
Distance between sensor and object (in.)	1/32	1/8	5/32	1/4
Min. diameter "d" of object to be sensed (in.)	5/64	5/32	1/8	25/64
b x h (in.)	1/8 x 1/16	1/8 x 1/4	1/8 x 1/4	1/8 x 3/8

FIGURE 2.15 AVAILABLE DATA-CONE JET SENSOR-FESTO

GEOMETRIC PROPERTIES

1.	Iden#	RFL-2	Dia. 0.9"	Lgth. 2.28"
2.	"	RFL-4	Dia. 0.9"	Lgth. 2.28"
3.	"	RFL-6	Dia. 0.9"	Lgth. 2.28"
4.	"	RFL-5	Dia. 0.5"	Lgth. 1.75"
5.	"	RFL-15	Dia. 0.9"	Lgth. 2.50"

NO FIGURE PROVIDED

NO LOGIC SYMBOL PROVIDED

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Festo Corporation

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive E.
Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: (Aug.76) $21.50 Model RFL-2, RFL-4, RFL-6
$16.00 Model RML-5, $25.00 RFL-15

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 160 Hz TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: 1.5 psi Maximum: 3.5 psi

FLOW-Minimum: 0.3 scfm, Model RFL-2 0.5 scfm, Model RFL-4, RML-5

0.6 scfm, Model RFL-6 1.7 scfm, Model RFL-15

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0.90" to .620"* MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN:

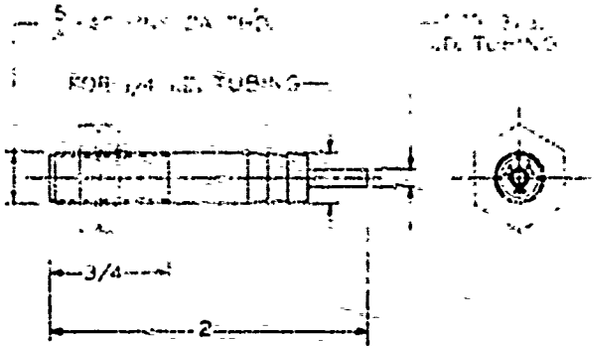
OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Depending upon Model



MODEL NO: PS105

NO LOGIC SYMBOL PROVIDED

FIGURE 2.16 CONE JET SENSOR-FORMSPRAG

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Formsprag Brochure X-3016 Part No. PS105

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 125°F

PRESSURE: U

POWER SUPPLY FILTRATION: 40 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Formsprag Co.
P.O. Box 778, 26444 Groesbeck Hwy.
Warren, Michigan 48089

POINT OF CONTACT: Mr. William H. Charlesworth (313) 758-5000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $14.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 30 cps

TIME RESPONSE: rise time 9ms; drop time 6ms

SUPPLY:	PRESSURE-Minimum:	4 psig*	Maximum:	4 psig*
	FLOW-Minimum:	1 scfm	Maximum:	1 scfm
	POWER-Minimum:	13 w	Maximum:	13 w
**OUTPUT:	PRESSURE-Minimum:	0.1 psig*	Maximum:	0.1 psig*
	FLOW-Minimum:	U	Maximum:	U
	POWER-Minimum:	U	Maximum:	U
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: U

SCALING ABILITY: None

LINEARITY: RANGE: NA

ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.190"

MINIMUM OBJECT SIZE: 0.25 Flat
0.38 Curved

HYSTERESIS: U

GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present.

CROSS SENSITIVITY EFFECTS: None

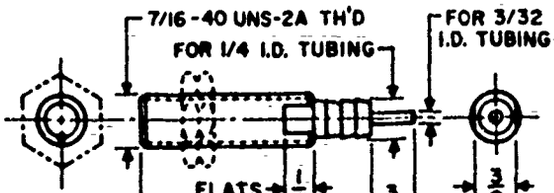
S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Nominal value

** Output measured at 4 psig supply & 3/16" target gap (output slightly below atmospheric pressure when nonactuated).



MODEL NO: PS307

NO LOGIC SYMBOL PROVIDED

FIGURE 2.17 CONE JET SENSOR-FORMSPRAG

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Formsprag Brochure 9231, Part No. PS307

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 350°F

PRESSURE: U

POWER SUPPLY FILTRATION: 40 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Formsprag Co.
P.O. Box 778, 26444 Groesbeck Hwy
Warren, Michigan 48089

POINT OF CONTACT: Mr. Wm. H. Charlesworth (313) 758-5000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $26.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 50 hz

TIME RESPONSE: 6 ms rise time; 10 ms fall time

SUPPLY: PRESSURE-Nominal 4 psig

FLOW-Nominal 0.8 scfm

POWER-Nominal 10.4 w

OUTPUT: PRESSURE-Minimum: See Figure 2.18

FLOW-Minimum:

POWER-Minimum:

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: None

LINEARITY: RANGE: NA

ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.25"

MINIMUM OBJECT SIZE: 0.25" Flat
0.38" Curved

HYSTERESIS: U

GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

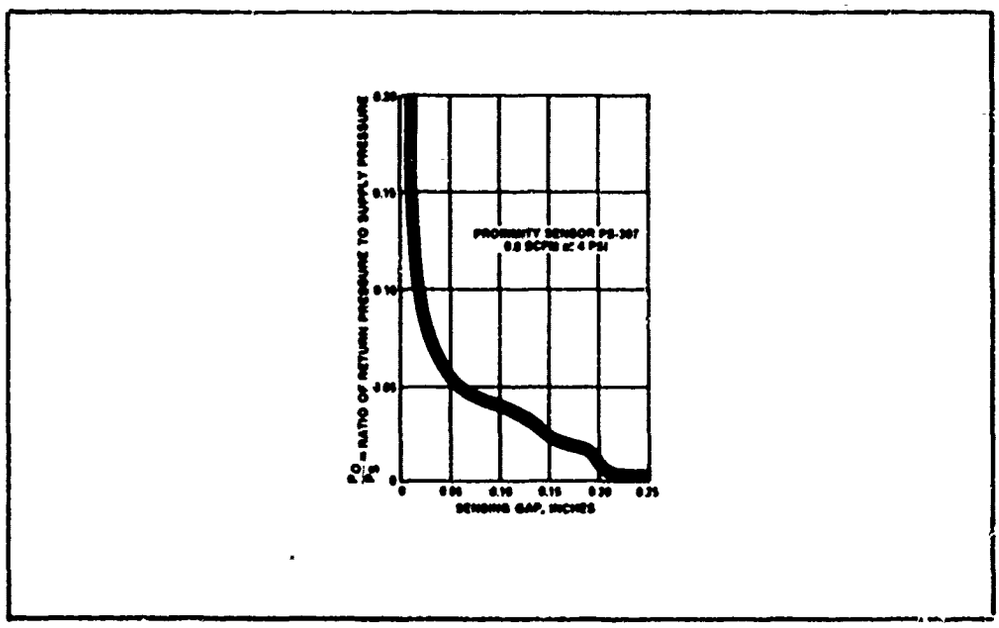


FIGURE 2.18 AVAILABLE DATA-CONE JET SENSOR-FORMSPRAG

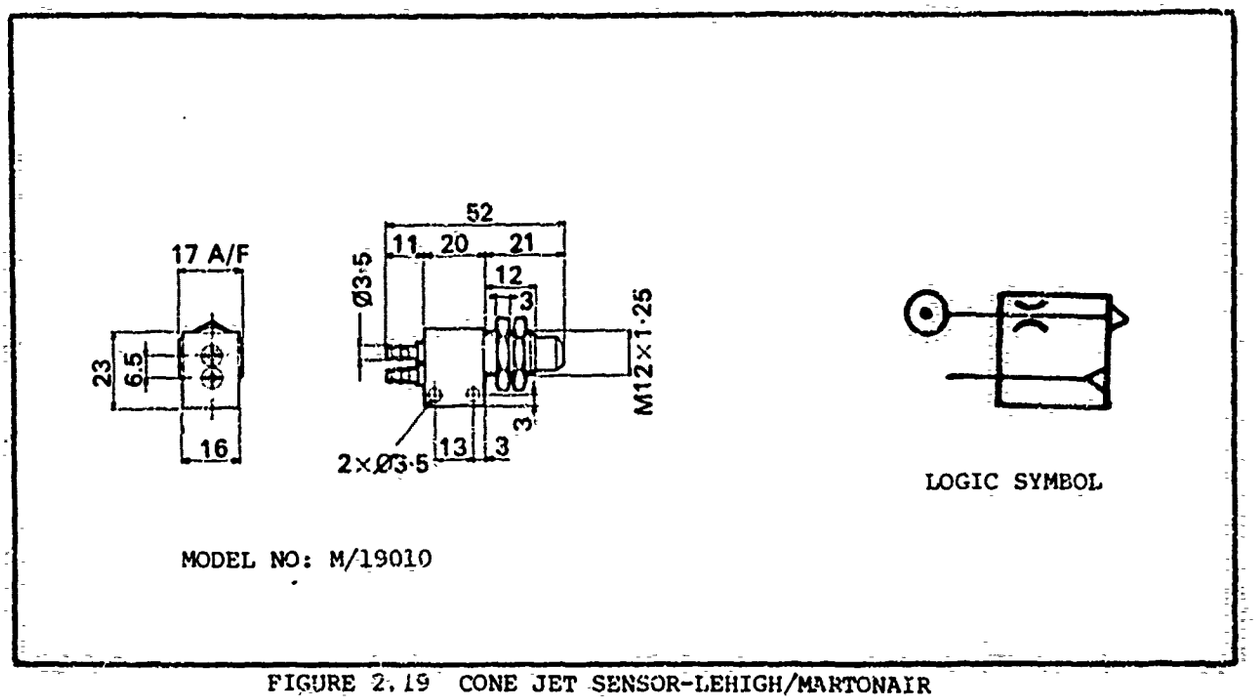


FIGURE 2.19 CONE JET SENSOR-LEHIGH/MARTONAIR

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Lehigh/Martonair Brochure: Part # M/19019

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -5^{o} to $+50^{o}C$ PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Lehigh Fluid Power Inc.
York Road, Route 179
Lambertville, N.J. 08530

POINT OF CONTACT: Mr. E.O. Ponder (609) 397-3487

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.20

OUTPUT: PRESSURE- See Figure 2.20

IMPEDANCE: U

SCALING ABILITY: N/A

LINEARITY: RANGE: N/A ACCURACY: U

OBJECT SENSING RANGE: 0 to 2mm MINIMUM OBJECT SIZE: 20 mm dia.

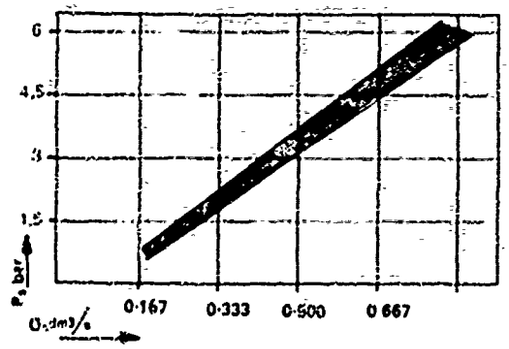
HYSTERESIS: U GAIN: NA

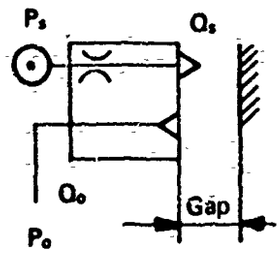
OUTPUT SIGNAL: Proportional pressure rise with presence of object

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: N/A EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U





NOTE: Total supply pressure range indicated.

FIGURE 2.20 AVAILABLE DATA-CONE JET SENSOR-LEHIGH/MARTONAIR

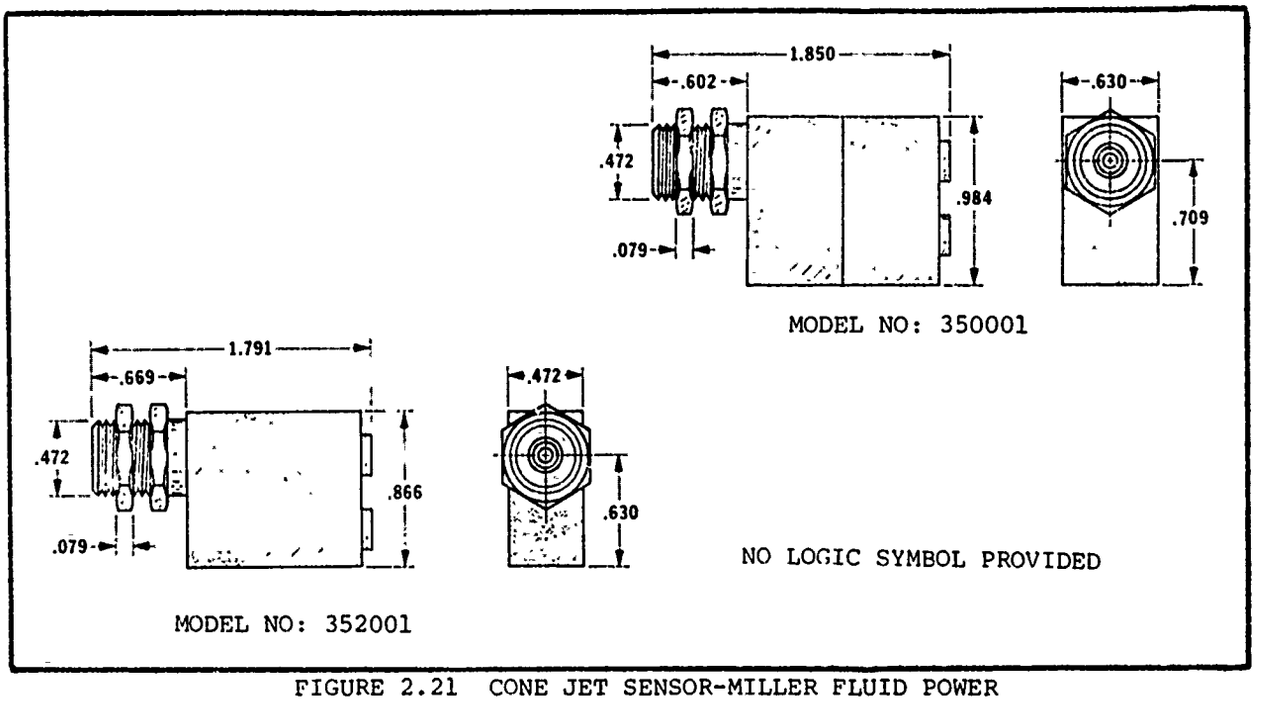


FIGURE 2.21 CONE JET SENSOR-MILLER FLUID POWER

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Miller Fluid Power Brochure No. 5746-1275

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Miller Fluid Power
7NO1ɔ York Road
Bensenville, Illinois 60106

POINT OF CONTACT: U (312) 766-3400

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 40 ms

SUPPLY: PRESSURE-Minimum: 45 psi Maximum: 105 psi

FLOW-Minimum: .6 scfm @ 75 psi Model 352001

POWER-Minimum: .46 scfm @ 75 psi Model 350001

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0" to 12" MINIMUM OBJECT SIZE: .039"X.118" Flat
.23" Curved

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

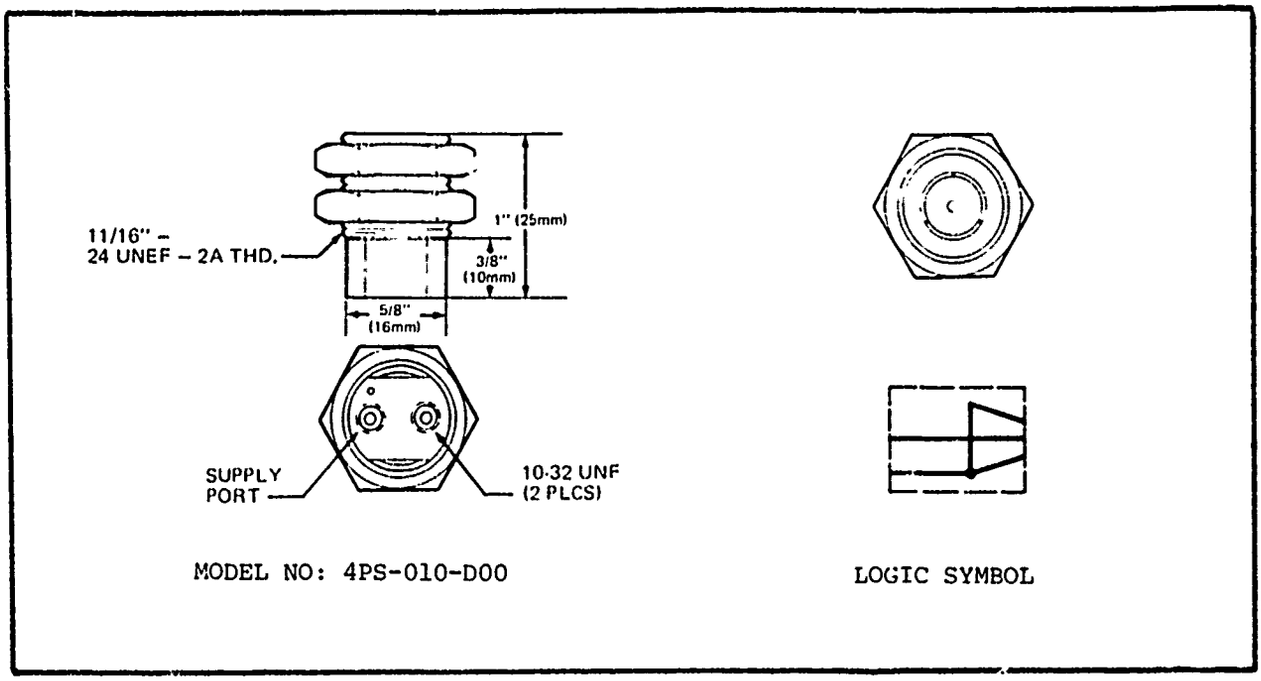


FIGURE 2.22 CONE JET SENSOR-NORGREN

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Norgren Brochure-Part # 4PS-010-000

PRIMARY FLUID: Air INTERFACE: Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: C A Norgren Co.
5400 S. Delaware Street
Littleton, Colorado 80120

POINT OF CONTACT: Mr. Robert Peterson (303) 794-2611

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 10 psi nominal,Flow: 0.36 Scfm nominal

OUTPUT: PRESSURE- See Figure 2.23

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: See Figure 2.23 ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.19" MINIMUM OBJECT SIZE: U

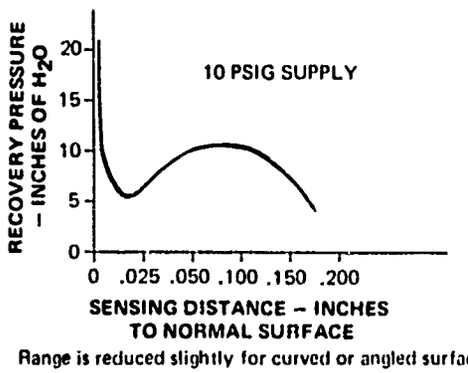
HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

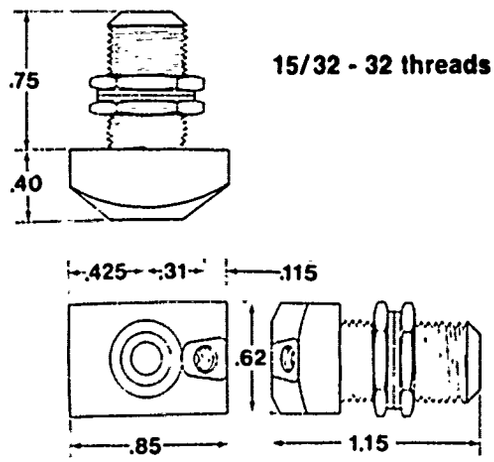
S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



USE A 5DA-010-D0A DIAPHRAGM AMPLIFIER WITH THIS SENSOR

FIGURE 2.23 AVAILABLE DATA-CONE JET SENSOR-NORGREN



NO LOGIC SYMBOL PROVIDED

MODEL NO: 1022

FIGURE 2.24 CONE JET SENSOR-NORTHEAST FLUIDICS

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Northeast Fluidics Brochure: Part # 1022

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Northeast Fluidics, Inc.
Clippard Instrument Labs
7390 Coleraine Road
Cincinnati, Ohio 45239

POINT OF CONTACT: (513) 521-4261

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $9.50 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE:	10 Hz		TIME RESPONSE:	U
SUPPLY: PRESSURE-Minimum:	4 psig		Maximum:	4 psig
FLOW-Minimum:	0.3 scfm		Maximum:	0.3 scfm
POWER-Minimum:	U		Maximum:	U
OUTPUT: PRESSURE-Minimum:	-2in(w)		Maximum:	+7.5in (w)
FLOW-Minimum:	See Figure 2.25		Maximum:	U
POWER-Minimum:	U		Maximum:	U
CONTROL: PRESSURE-Minimum:	NA			

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0" to .1" MINIMUM OBJECT SIZE: .25" X .25"

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: NA

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

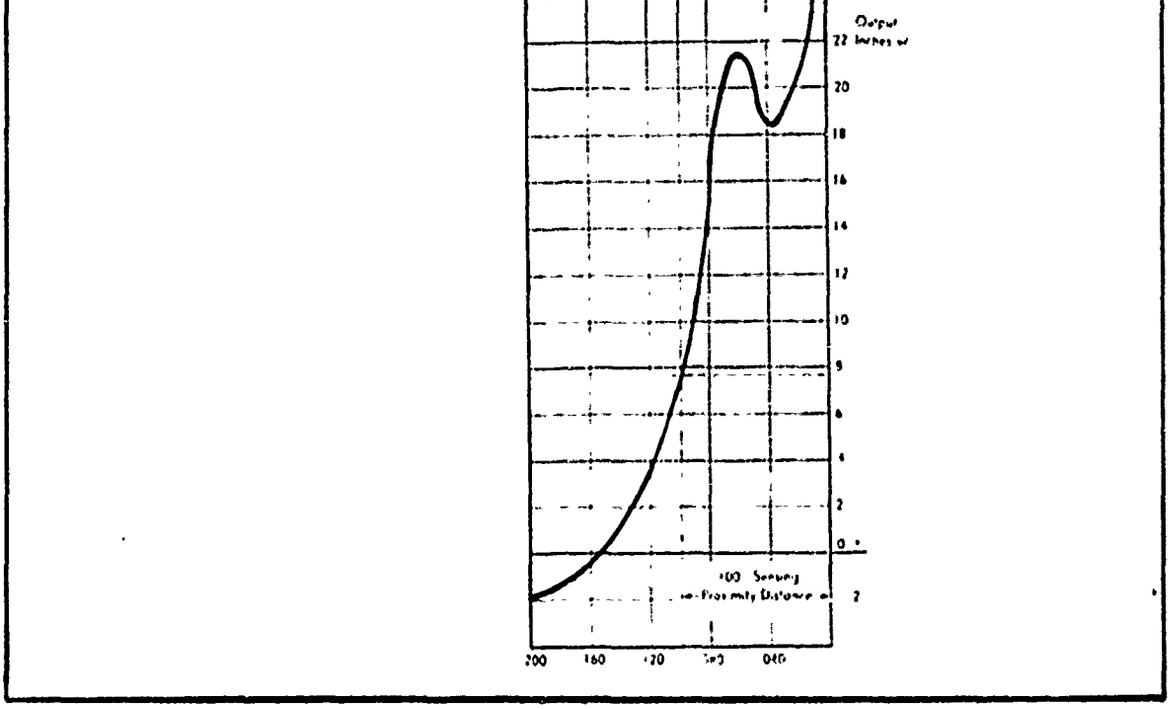


FIGURE 2.25 AVAILABLE DATA-CONE JET SENSOR-NORTHEAST FLUIDICS

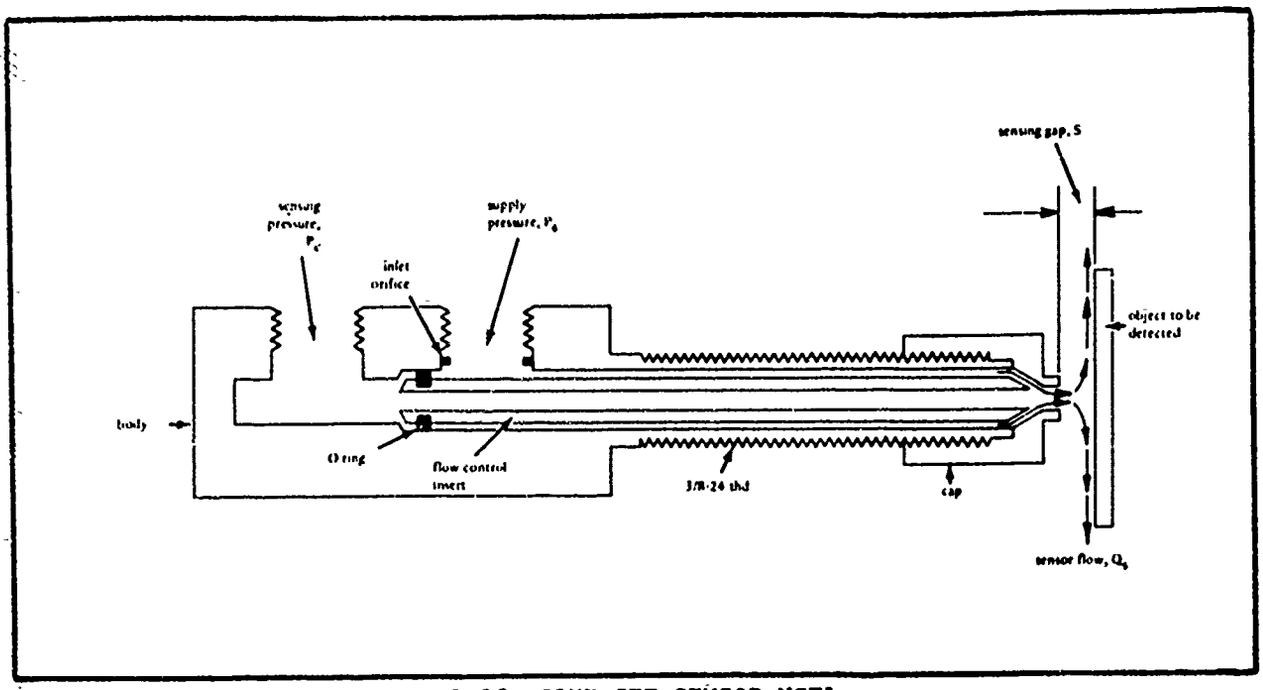


FIGURE 2.26 CONE JET SENSOR-NCEL

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone Jet

DATA SOURCE: Technical Note N-1349, Naval Civil Engineering Laboratory

PRIMARY FLUID: Hydraulic Oil INTERFACE: Oil, Fluidic

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 125° to 150°F PRESSURE: 1000 psig

POWER SUPPLY FILTRATION: Yes, micron size filter not specified

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient Oil Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Naval Civil Engineering Laboratory
Construction Battalion Center
Port Hueneme, California 93043

POINT OF CONTACT: E.R. Durlak, Code L-63 (805)982-5336

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U			TIME RESPONSE: U	
SUPPLY:	PRESSURE-Minimum:	200-300 psig	Maximum:	1000 psig
	FLOW-Minimum:	1.16 gpm	Maximum:	3 gpm
	POWER-Minimum:	U	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	2 psig	Maximum:	150 psig
	FLOW-Minimum:	1.15 gpm	Maximum:	3 gpm
	POWER-Minimum:		Maximum:	
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: 0 to 12" sensing gap ACCURACY: U

OBJECT SENSING RANGE: .015" to .100" MINIMUM OBJECT SIZE: U

HYSTERESIS: NA GAIN:

OUTPUT SIGNAL: Pressure rise, See Figure 2.27

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: Unlimited

MTBF: U MCBF: U MTTR: U

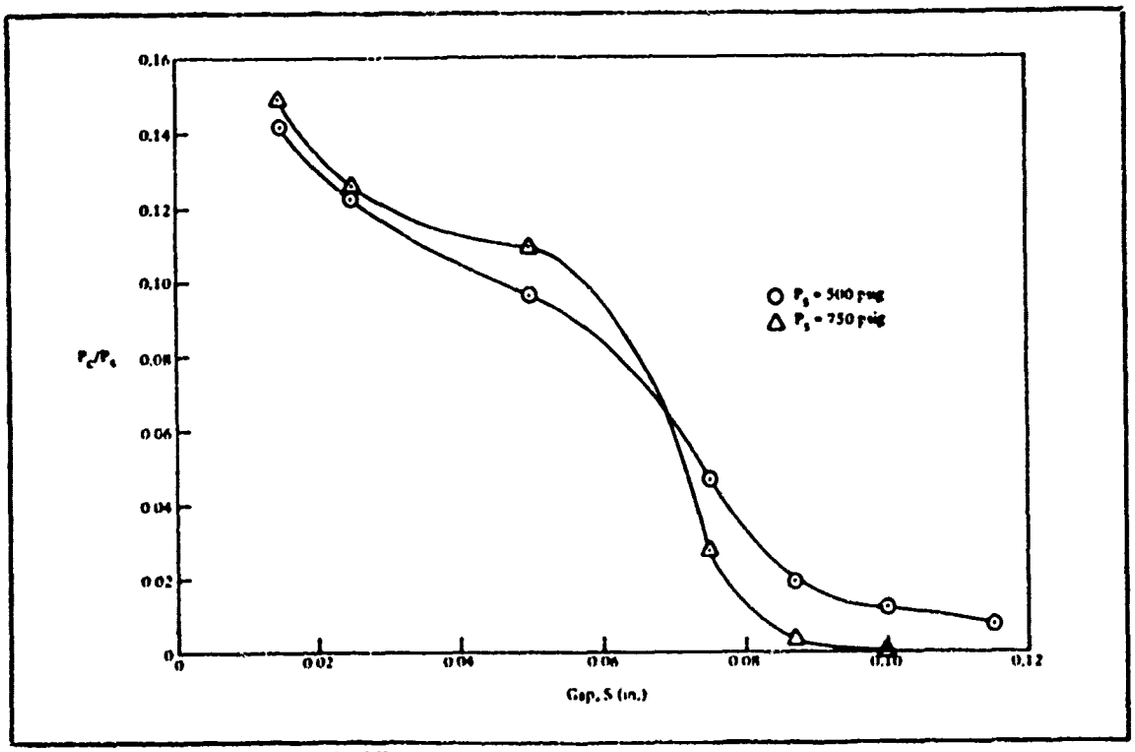


FIGURE 2.27 AVAILABLE DATA-CONE JET SENSOR-NCEL

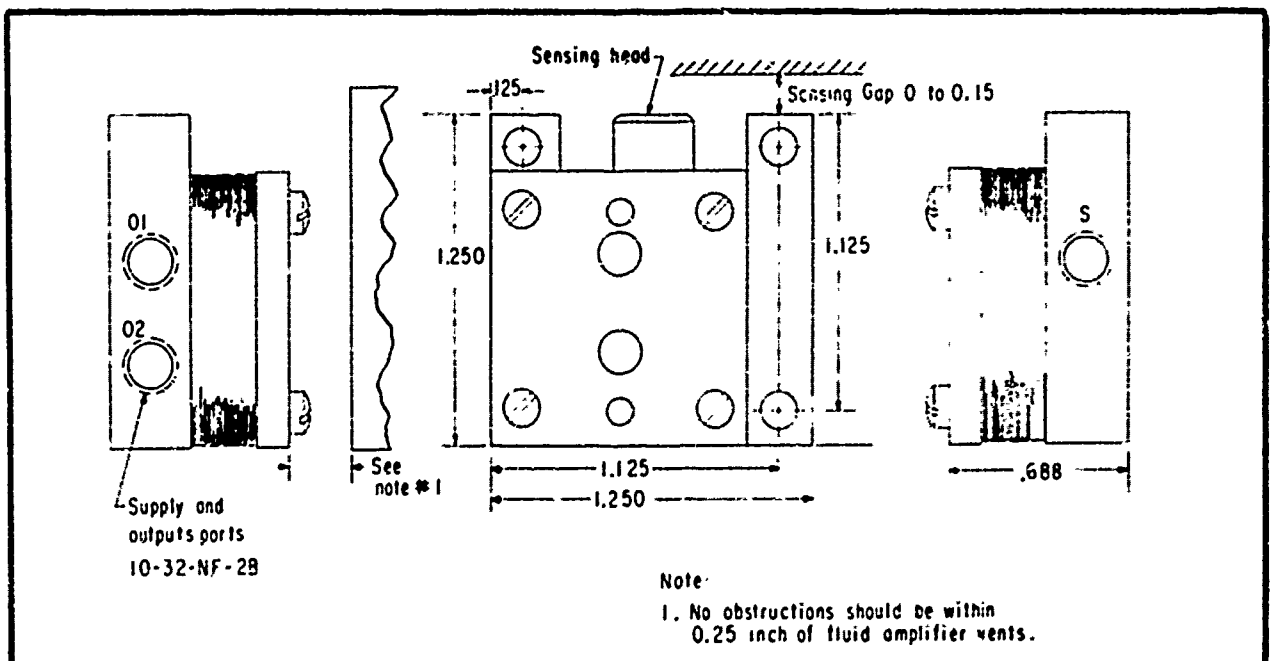


FIGURE 2.28 CONE JET SENSOR - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Proximity/Amplifier MOVING PARTS: None

PRINCIPLE OF OPERATION: Cone-Jet

DATA SOURCE: General Electric Brochure: Model #24PS21AA

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: To 100°C PRESSURE: 15 psig

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: To 500 Hz TIME RESPONSE: 2 ms

SUPPLY: PRESSURE- 5 to 15 psig (See Figure 2.29)

OUTPUT: PRESSURE- 4 psig at 15 psig supply pressure

IMPEDANCE: 0.8 scfm at P_s = 10 psig

SCALING ABILITY: NA

LINEARITY: RANGE: To 15 psig ACCURACY: U

OBJECT SENSING RANGE: Up to 0.15 inch MINIMUM OBJECT SIZE: U

HYSTERESIS: NA GAIN: U

OUTPUT SIGNAL: Pressure

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U EXPECTED LIFE: Unlimited

MTBF: U MCBF: U MTTR: U

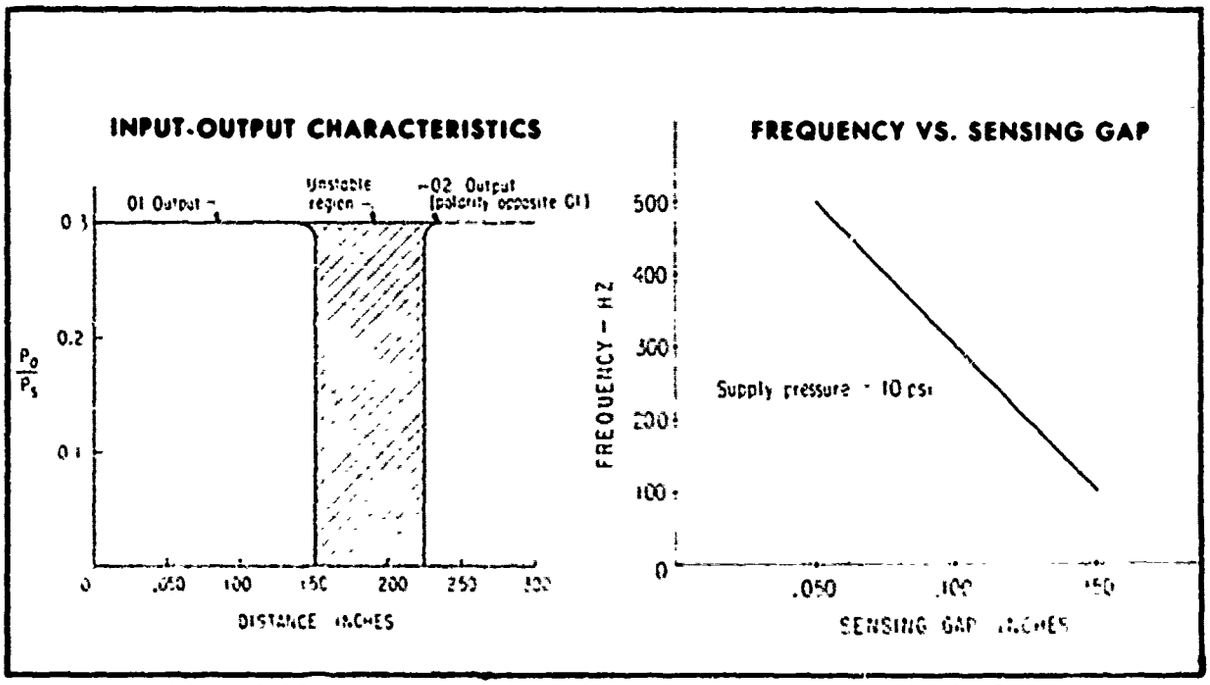


FIGURE 2.29 AVAILABLE DATA: CONE JET SENSOR - TRITEC, INC.

2.2.2 Vortex Proximity Sensor

The basic operation of a vortex proximity sensor is shown in Figure 2.30. The vortex chamber is used to generate a swirling flow in the shape of a diverging cone. This high-velocity vortical flow entrains ambient air, thereby maintaining essentially atmospheric pressure within the cone. At the vertex of this cone is a sensing/output port. The introduction of any object in the conical region restricts the replenishment of the entrained flow, and a local pressure reduction occurs. The resultant signal is negative pressure, relative to that which existed for the sensor in an unobstructed state. With a vortex proximity sensor, the output is analog and is inversely proportional to the gap between the sensor and the object. Because of the low gain of this type of sensor, the device is usually coupled to a high gain amplifier, or if a digital signal is required, to a Schmitt trigger.

One of the largest drawbacks with this type of system is that the output depends upon entrained air from the atmosphere, thus introducing a high probability of contamination of the sensor. Commercial manufacturers claim, however, that this is not a severe problem since positive output pressures tend to prohibit contaminants from entering the internal parts of the system. Further, periodic cleaning can minimize any contaminant buildup. Manufacturers claim that the maximum sensitivity range of a vortex sensor is in the order of 0.5 to 0.75 inch. The minimum object size required is 0.375 inch square, and thus the sensor does not lend itself to sensing wire or any other extremely small object.

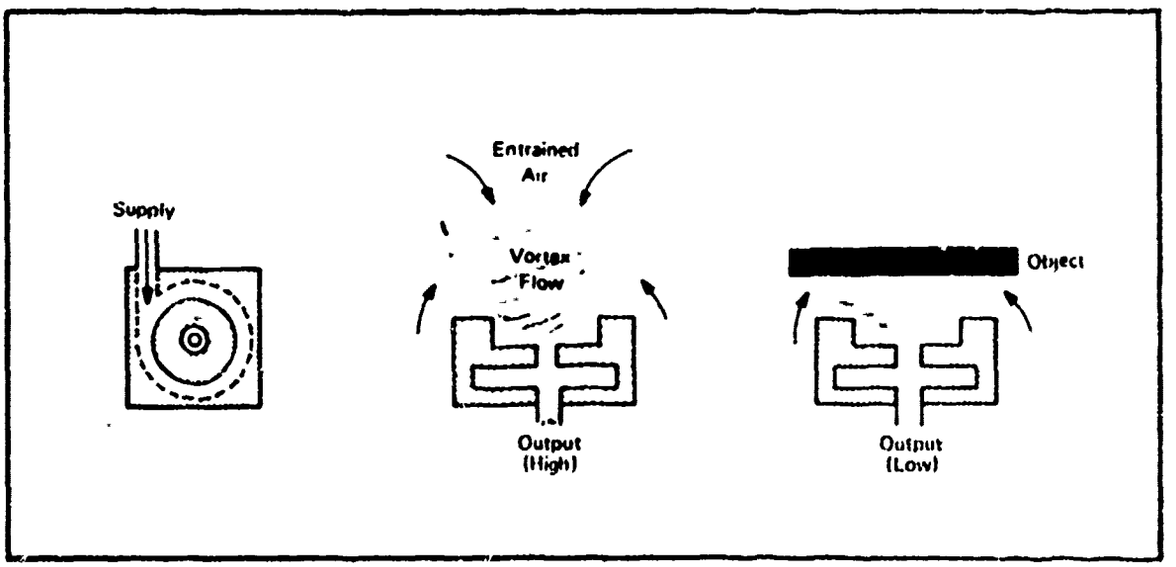


FIGURE 2.30 BASIC VORTEX PROXIMITY SENSOR OPERATION

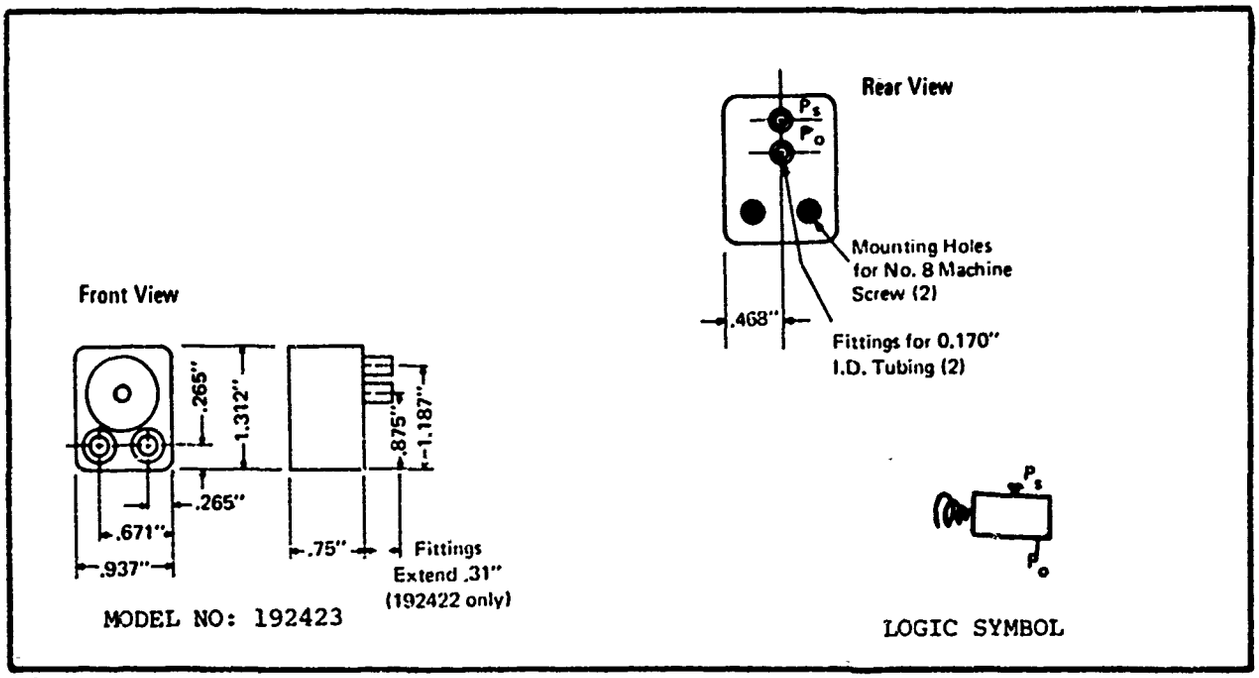


FIGURE 2.31 VORTEX-PROXIMITY SENSOR-CORNING

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Vortex

DATA SOURCE: Corning Fluidic Products Brochure: Part # 192423

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Corning Glass Works
Fluidic Products Department
Corning, N.Y. 14830

POINT OF CONTACT: William T. Greenfield Jr. (607)974-8147

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $15.40 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: See Table

SUPPLY: PRESSURE- See Figure 2.32

OUTPUT: PRESSURE- 1% P (supply) Max. 30% P (supply)

IMPEDANCE: Fanout into 1 FICM (Corning) Schmitt Trigger only

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.5" MINIMUM OBJECT SIZE:.375"x.375" Flat

HYSTERESIS: .1875" to .3125" GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

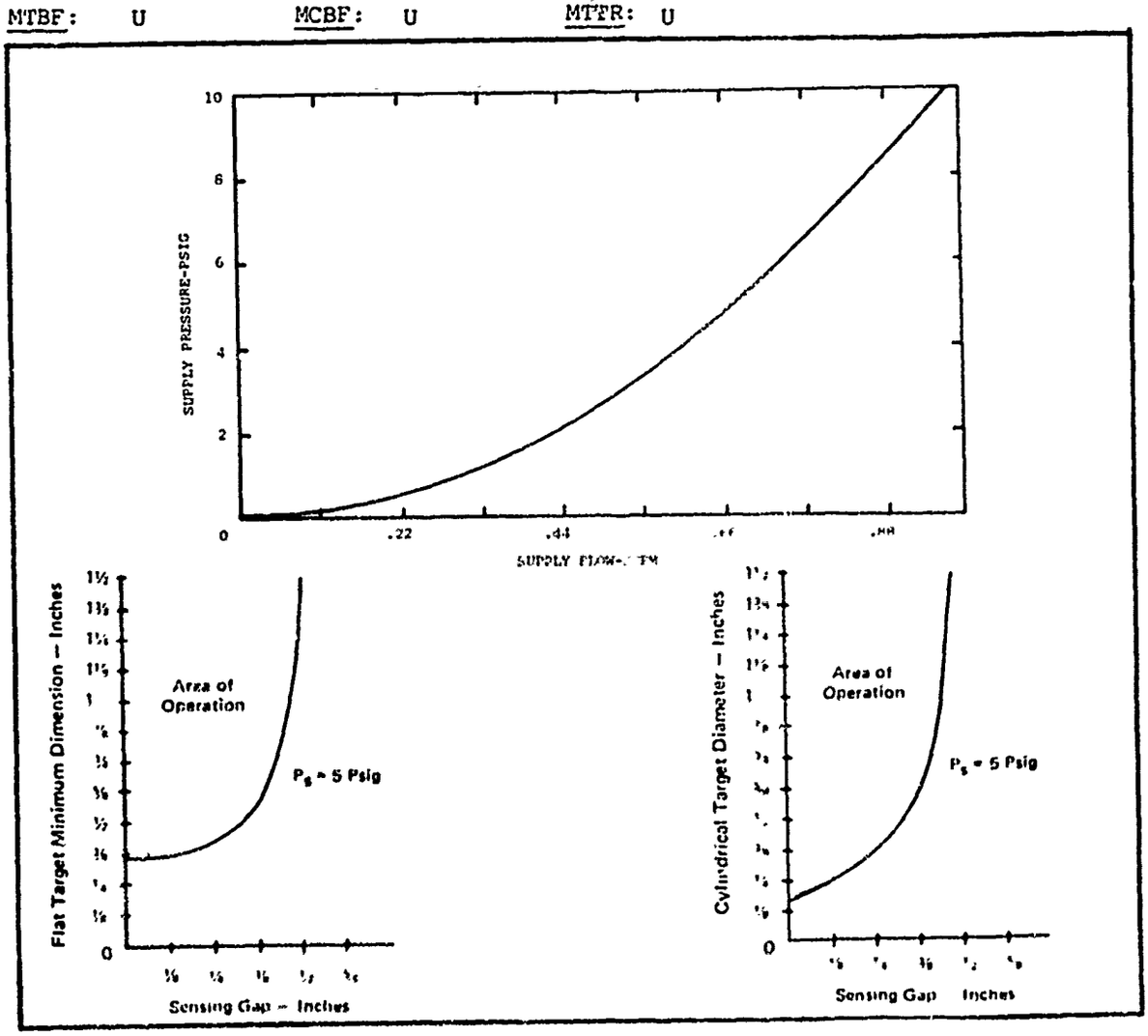


FIGURE 2.32 AVAILABLE DATA-VORTEX SENSOR-CORNING

2.2.3 Annular Nozzle Proximity Sensor

A longer range sensor, which employs a variation of the basic principles of the cone-jet and vortex devices, uses a diverging, swirl-free annular nozzle. Jet entrainment causes this divergent conical flow to converge at some distance from the nozzle. Within the oval thus formed as shown in Figure 2.33, the pressure is substantially reduced and when this low pressure pattern becomes disturbed by an obstruction, an abrupt pressure bubble burst takes place and the pressure becomes that of atmospheric. To accentuate the sudden pressure rise, the pressure sensing port is situated within the bubble near the point where the jet makes its sharpest turn. When the bubble breaks, the jet shifts away from the output opening therefore inducing a maximum pressure rise.

Because this device employs a pressurized power supply (and essentially no atmospheric air is entrained), it is relatively contamination free. Manufacturers claim that the maximum sensitivity range of this type of sensor is approximately 1.125 inches, and that this distance is relatively independent of changes in supply pressure. Unfortunately, with this type of sensor only a relatively large object can be sensed, i.e., on the order of 1.5 inches square; therefore, the device does not lend itself to applications such as sensing a wire or even serving as an edge guide mechanism.

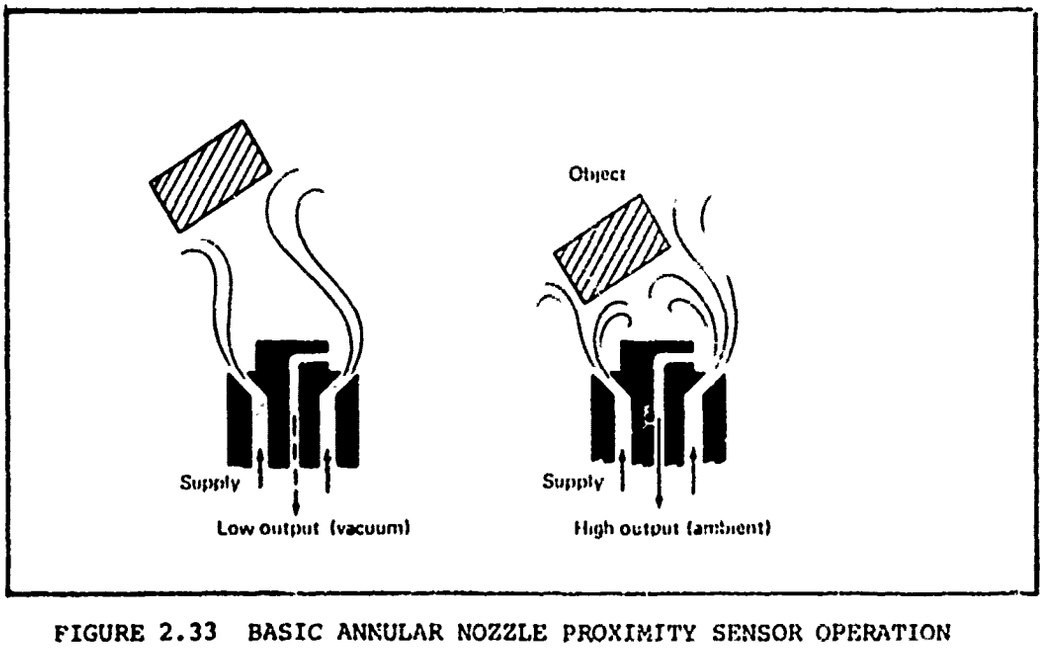


FIGURE 2.33 BASIC ANNULAR NOZZLE PROXIMITY SENSOR OPERATION

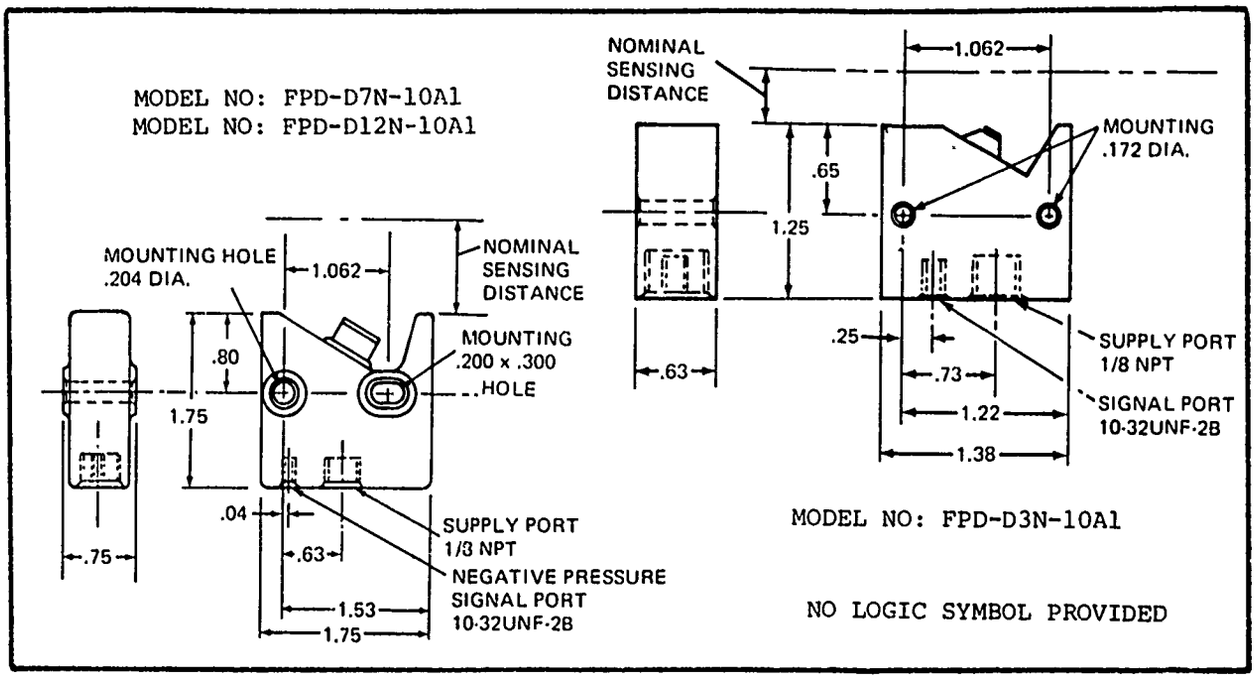


FIGURE 2.34 ANNULAR NOZZLE-PROXIMITY SENSOR-BROWN & SHARPE

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Annular Nozzle Sensor

DATA SOURCE: Brown & Sharpe Brochure: P-14123

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Double A. Division
Brown & Sharpe Mfg. Inc.
715 East Duncan Street
Manchester, Michigan 48158

POINT OF CONTACT: (313) 428-8311

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 100 Hz TIME RESPONSE: 10 ms

SUPPLY:	PRESSURE-Minimum:	3 psig	Maximum:	4 psig
	FLOW-Minimum:	0.4 scfm	Maximum:	1.4 scfm
	POWER-Minimum:	U	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	-0.14 psig	Maximum:	+ 0.108 psig
	FLOW-Minimum:	U	Maximum:	U
	POWER-Minimum:	U	Maximum:	U
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: Recommends use of amplifier FPA-2N-10A1

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to 1.2" MINIMUM OBJECT SIZE:

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

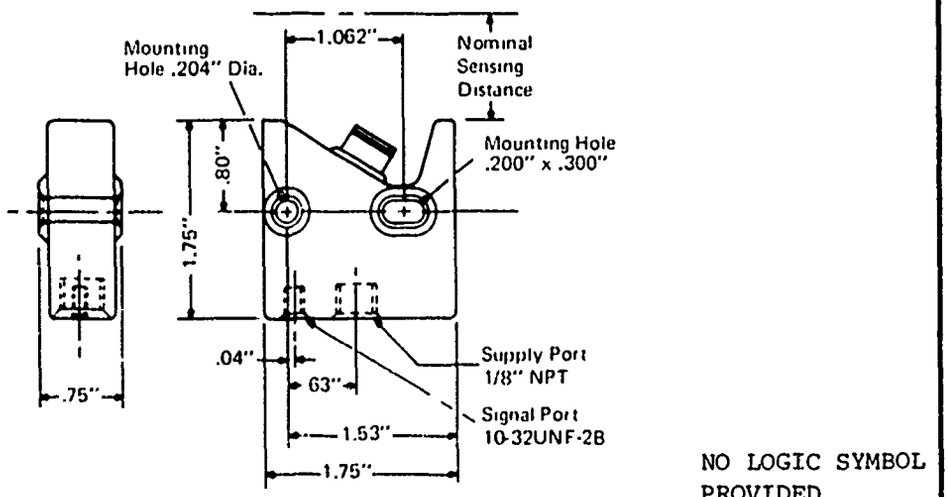


FIGURE 2.35 ANNULAR NOZZLE-PROXIMITY SENSOR-CORNING

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Annular Nozzle Sensor

DATA SOURCE: Corning Fluidic Products Brochure; Part # 190009

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Corning Glass Works
Fluidic Products Department
Corning, N.Y. 14083

POINT OF CONTACT: William T. Greenfield Jr. (607) 974-8147

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $65.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 5 Hz TIME RESPONSE: 0.30 sec

SUPPLY:	PRESSURE-Minimum:	3 psig	Maximum:	10 psig
	FLOW-Minimum:	1.3 scfm*	Maximum:	U
	POWER-Minimum:	U	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	U	Maximum:	U
	FLOW-Minimum:	U	Maximum:	U
	POWER-Minimum:	U	Maximum:	U
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to 1.125" MINIMUM OBJECT SIZE: 1.5"x1.5"Flat

HYSTERESIS: 0.50" to 0.75" GAIN: NA

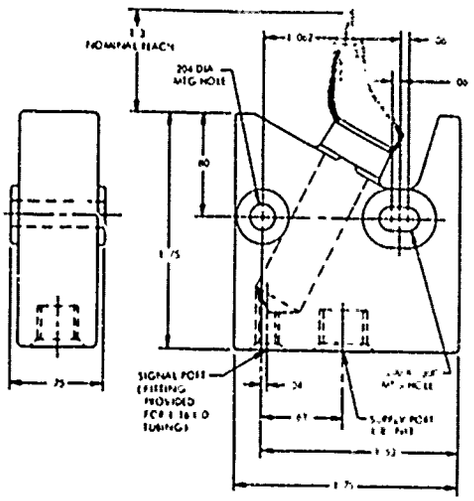
OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Flow at 5 psig.



MODEL NO: SFX18C

NO LOGIC SYMBOL PROVIDED

FIGURE 2.36 ANNULAR NOZZLE-PROXIMITY SENSOR-GAGNE

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Annular Nozzle Sensor

DATA SOURCE: Gagne Information Bulletin: Part # SFX18C

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Gagne Assoc. Inc.
1080 Chenango Street
Binghamton, N.Y. 13901

POINT OF CONTACT: Mr. A. F. Gagne (607) 723-9556

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $55.00

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE:	90 Hz		TIME RESPONSE:	U
SUPPLY: PRESSURE-Minimum:	3 psig		Maximum:	10 psig
FLOW-Minimum:	1.25 scfm		Maximum:	U
POWER-Minimum:	U		Maximum:	U
OUTPUT: PRESSURE-Minimum:	U		Maximum:	0.361 psi
FLOW-Minimum:	U		Maximum:	U
POWER-Minimum:	U		Maximum:	U
CONTROL: PRESSURE-Minimum:	NA			

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to 1.3" MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise from negative to zero with object present

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

2.2.4 Interruptible Jet Proximity Sensor

The interruptible jet sensor is one of the most common of all the fluidic proximity sensors currently available. Variations of its basic principle of operation are shown in Figure 2.37. It is by far the simplest in concept since it requires only a supply tube and a coaxial receiver tube separated by a specific gap region. With no object interrupting the flow supply through this gap, the pressure recovered in the receiver is nearly equal to that of the supply (with minimum losses due to gap spacing). The insertion of any object in the gap reflects and/or impedes supply flow to the receiver thus causing a pressure drop for the device shown in Figure 2.37a, or a pressure increase for the device shown in Figure 2.37b.

Manufacturers claim that the interruptible jet sensor will sense any flat or round object with a .032 in. minimum radius within a maximum sensitivity range of 0.5 inch. There are two basic configurations of the interruptible jet sensor. In Figure 2.37a, the output signal is due to air captured by the receiver, and contamination may occur due to entrainment of ambient air along with the jet. In Figure 2.37b, the sensor emits flow from both the emitter and the receiver. Since ambient air is not entrained, the possibility of contamination is minimized. It is also possible to employ a technique known as "cross-fire," whereby a jet is placed at a 90° angle to the interruptible jet emitter and receiver. The use of this technique is dependent upon such factors as the size of the object, the supply pressure to the primary jet, and the sensitivity of the switching element.

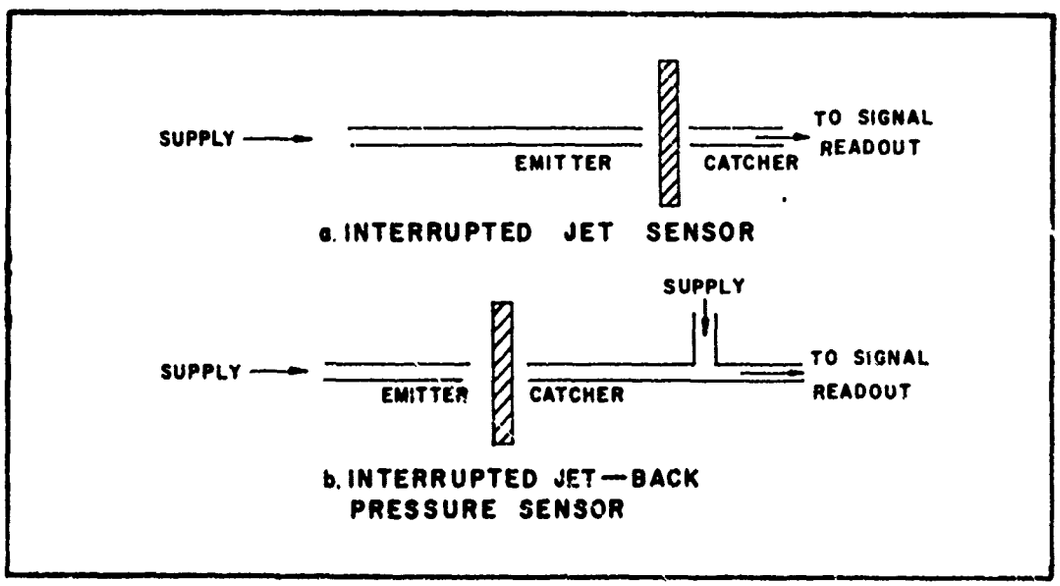
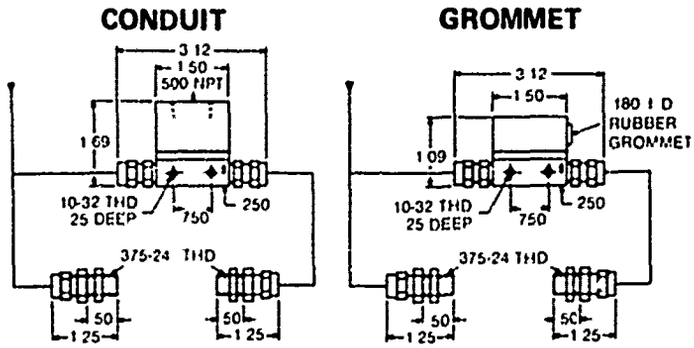


FIGURE 2.37 BASIC INTERRUPTIBLE JET PROXIMITY SENSOR OPERATION



MODEL NUMBERS	CONDUIT	GROMMET
AIR SENSING	30-0681	30-0713
LIQUID SENSING	30-0682	30-0714

NO LOGIC SYMBOL PROVIDED

FIGURE 2.38 INTERRUPTIBLE JET-PROXIMITY SENSOR-AIRMATIC/BECKETT-HARCUM

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: Diaphragm in sensing body

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Airmatic/Beckett-Harcum Brochure

PRIMARY FLUID: Air, liquid

INTERFACE: Air-Air, Liquid-Liquid

READOUT PROVIDED: Electrical

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 105°C

PRESSURE: 50 psi

POWER SUPPLY FILTRATION: 50 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Airmatic/Beckett-Harcum
185 Park Drive
Wilmington, Ohio 45177

POINT OF CONTACT: Mr. Cliff Howard (513) 382-1691

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 50 Hz TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.39

OUTPUT: PRESSURE- See Figure 2.39

IMPEDANCE: NA

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: See Figure 2.39 MINIMUM OBJECT SIZE:

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Electrical SPDT switch, 10a, 125 or 250v AC

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: NA EXPECTED LIFE: 10,000,000 operations

MTBF: U MCBF: U MTTR: U

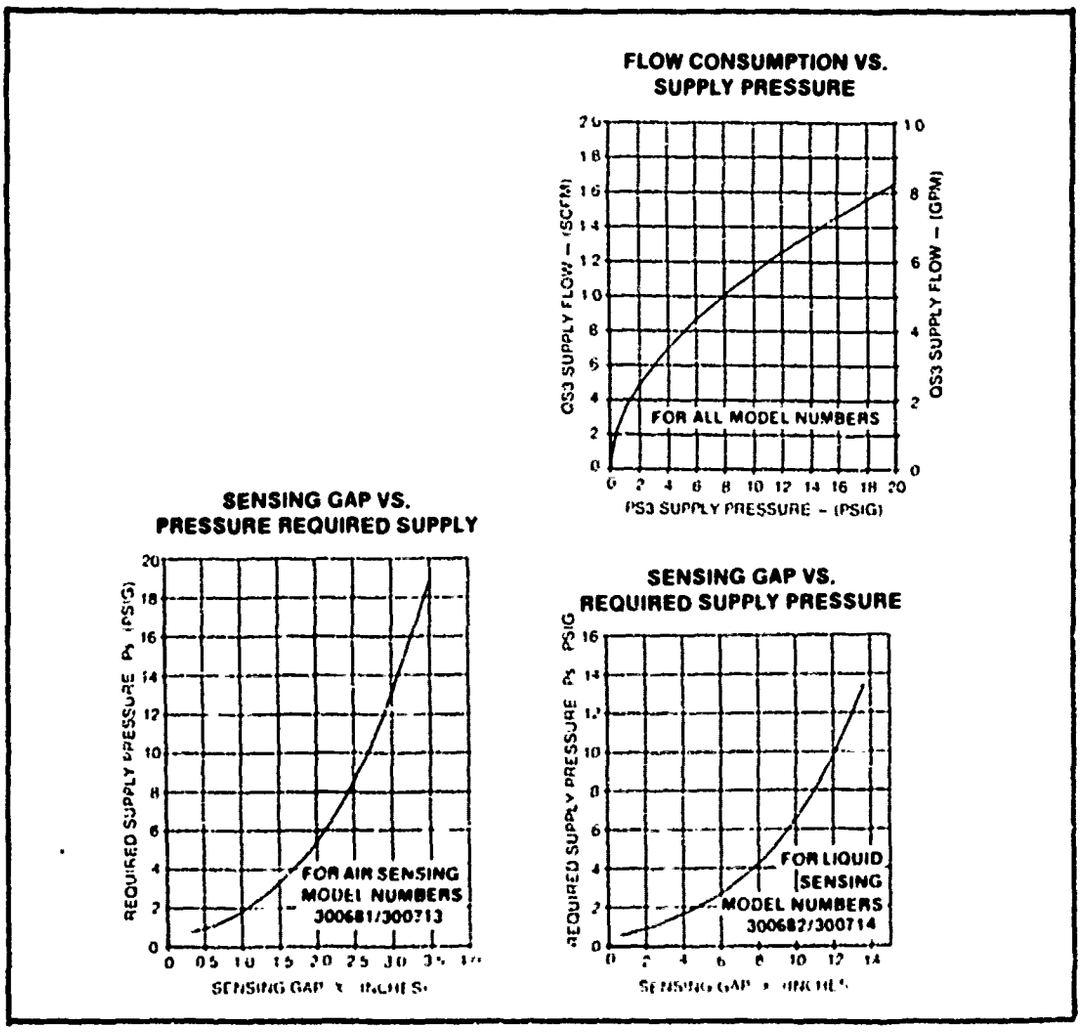


FIGURE 2.39 AVAILABLE DATA-INTERRUPTIBLE JET SENSOR-AIRMATIC/BECKETT-HARCUM

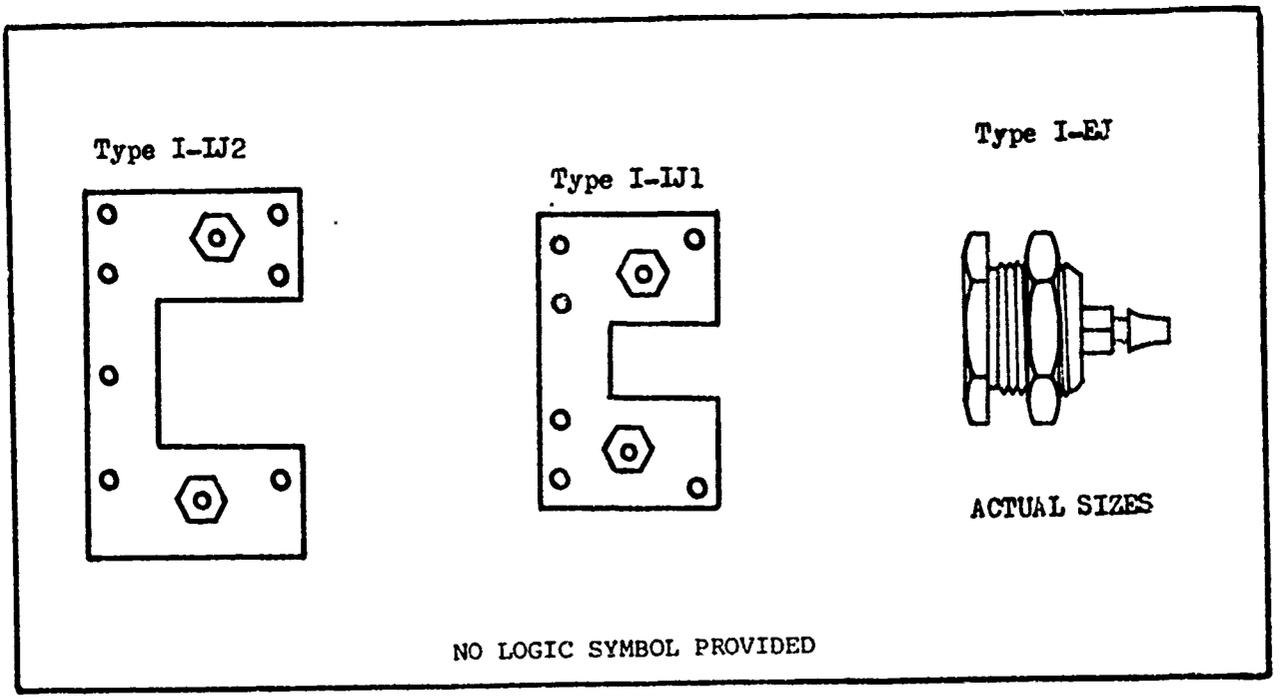


FIGURE 2.40 INTERRUPTIBLE JET-PROXIMITY SENSOR-BRITISH FLUIDICS AND CONTROLS

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: British Fluidics and Controls Brochure

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: to 100°C PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: British Fluidics and Controls Ltd.
Forest Road
Essex England

POINT OF CONTACT: Mr. N.W. Sykes

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.41

OUTPUT: PRESSURE- See Figure 2.41

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.41

ACCURACY: U

OBJECT SENSING RANGE: 10mm type I-IJ1
10mm type I-IJ2

MINIMUM OBJECT SIZE: U

HYSTERESIS: U

GAIN: NA

OUTPUT SIGNAL: Digital pressure change

CROSS SENSITIVITY EFFECTS: None

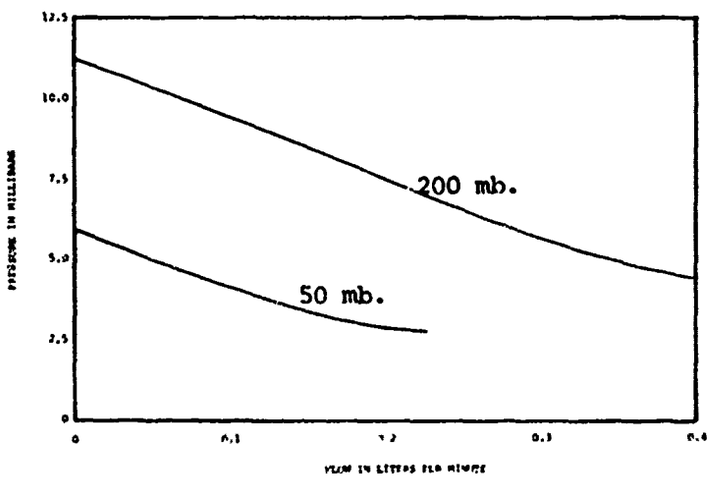
S/N RATIO: U

EXPECTED LIFE: U

MTBF: U

MCBF: U

MTTR: U



NOTE: Curves are for Types I-IJ1, and I-IJ2 only, Type I-EJ is used as a crossfire nozzle for distances up to 0.5 meter.

FIGURE 2.41 AVAILABLE DATA-INTERRUPTIBLE JET SENSOR-BRITISH FLUIDICS AND CONTROLS

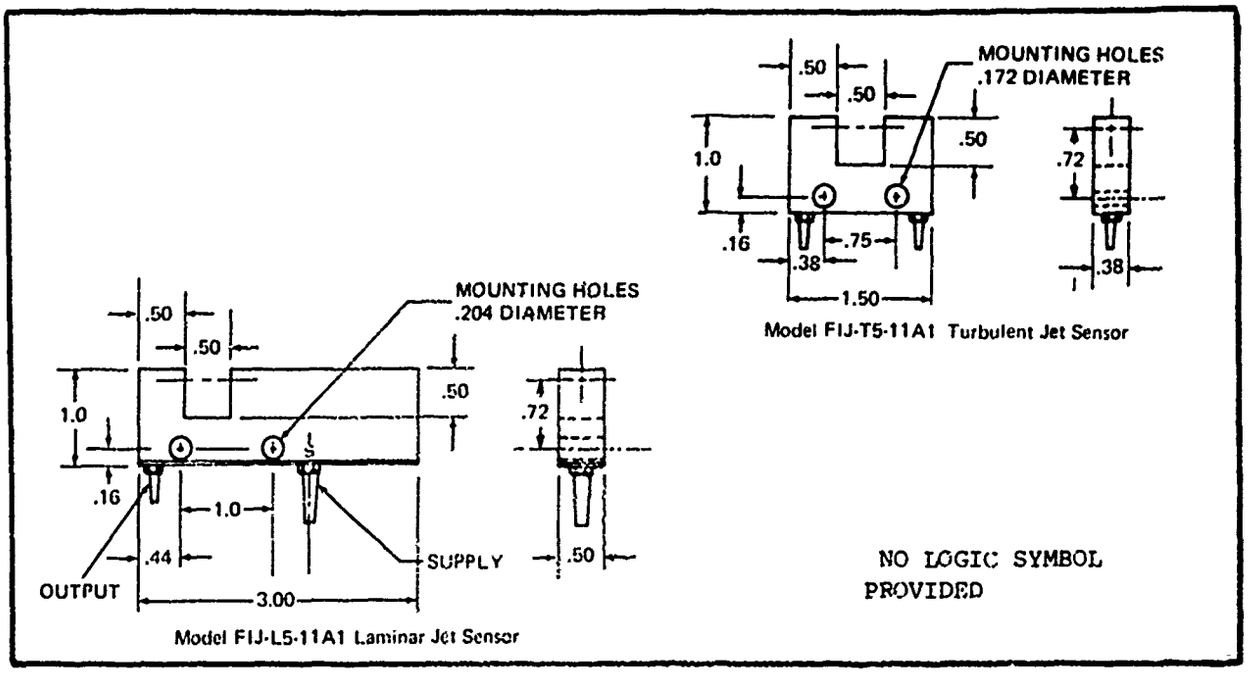


FIGURE 2.42 INTERRUPTIBLE JET-PROXIMITY SENSOR-BROWN AND SHARPE

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Brown & Sharpe Brochure

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: Yes (U) NOISE: Yes (U)

ACCELERATION: Yes (U) VIBRATION: Yes (U)

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Double A Products
Brown & Sharpe Mfg. Co.
715 East Duncan Street
Manchester, Michigan 48158

POINT OF CONTACT: (313) 428-8311

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 100 Hz TIME RESPONSE: U

SUPPLY: PRESSURE-Nominal: 3.0 psig (Model T-5)

PRESSURE-Nominal: 0.36 psig (Model L-5)

OUTPUT: PRESSURE-Nominal: 0.30 psig (Model T-5)

PRESSURE-Nominal: 0.15 psig (Model L-5)

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: Recommend useage of B&S amplifier FPA-1P-10A1

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0.5" MINIMUM OBJECT SIZE: .003" diameter

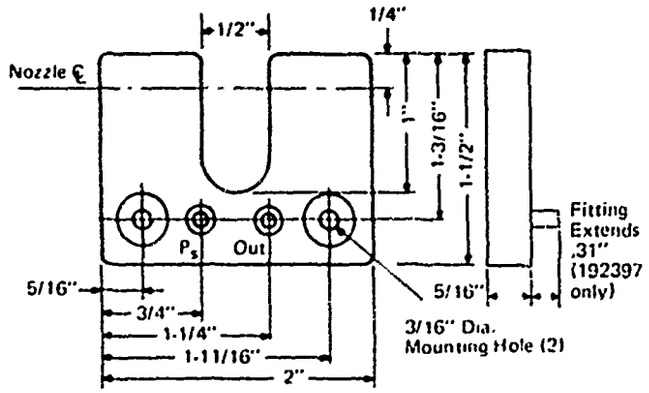
HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure falls from Max. to near zero when object is present

CROSS SENSITIVITY EFFECTS: Wind, Noise, and Vibration

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



MODEL NO: 192397

NO LOGIC SYMBOL PROVIDED

FIGURE 2.43 INTERRUPTIBLE JET-PROXIMITY SENSOR-CORNING

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Corning Fluidic Products Brochure Part # 192397

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: U

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Corning Glass Works
Fluidic Products Dept.
Corning, N.Y. 14830

POINT OF CONTACT: William T. Greenfield Jr. (607) 974-8147

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $16.50 each

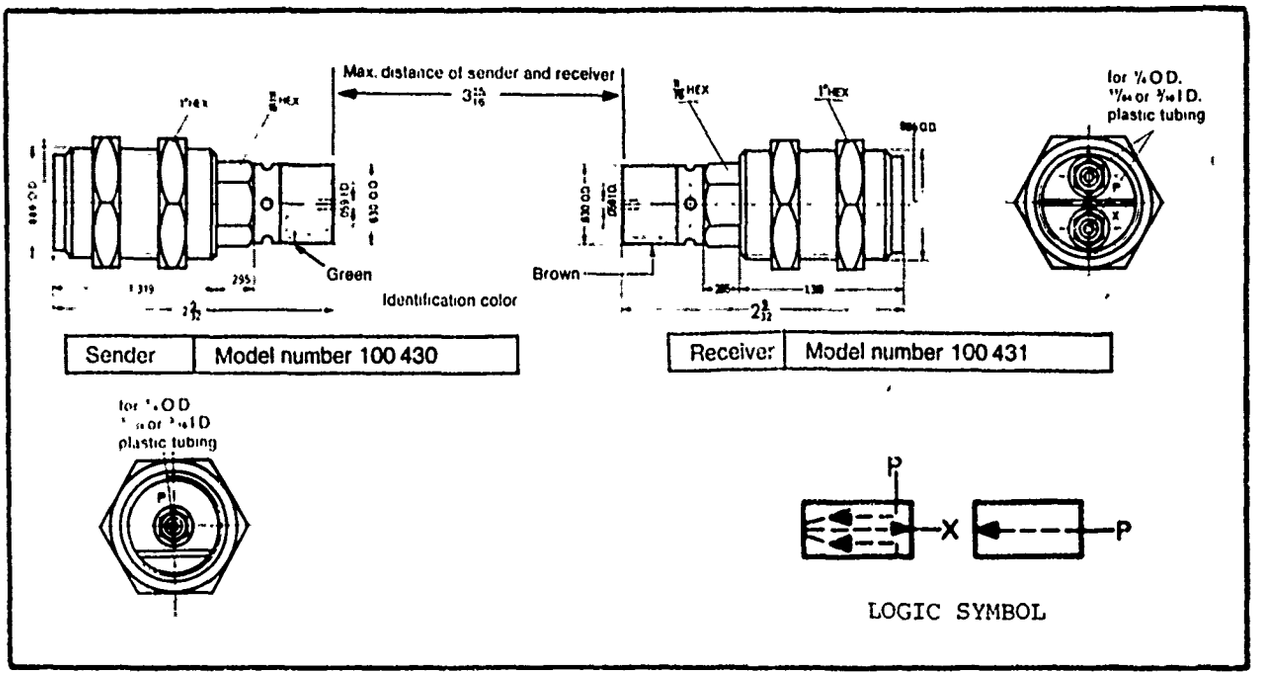


FIGURE 2.47 INTERRUPTIBLE JET-PROXIMITY SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Festo Brochure 1000-3

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: 55 psi Sender, 7 psi receiver

POWER SUPPLY FILTRATION: 25 micron, dry air

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

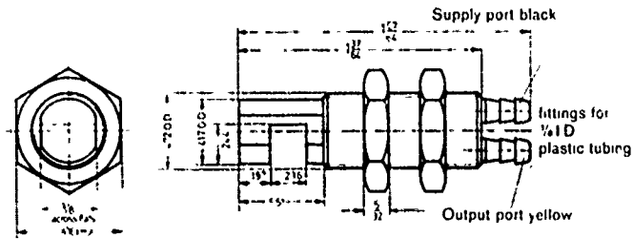
ORDERING INFORMATION

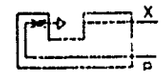
MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive, E.
Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $15.00 each Model 100430
$12.00 each Model 100431





LOGIC SYMBOL

MODEL NO: 004 439

FIGURE 2.45 INTERRUPTIBLE JET-PROXIMITY SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Festo Brochure:1000-3 Part No. 004439

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: 25 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

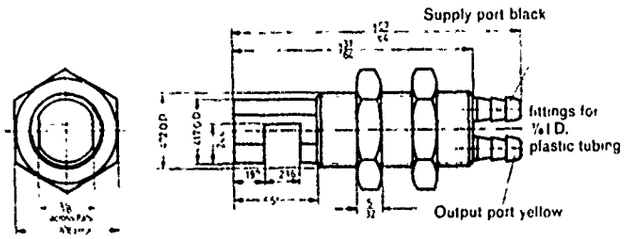
ORDERING INFORMATION

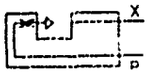
MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive. E.
Port Washington, N.Y. 11050
(516) 883-8571

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $13.00 each





LOGIC SYMBOL

MODEL NO: 004 439

FIGURE 2.45 INTERRUPTIBLE JET-PROXIMITY SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Festo Brochure:1000-3 Part No. 004439

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: 25 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive. E.
Port Washington, N.Y. 11050
(516) 883-8571

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $13.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.46

OUTPUT: PRESSURE- See Figure 2.46

IMPEDANCE: To drive Festo High Pressure Amplifier #007 098

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.25" MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Digital Pressure drop with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

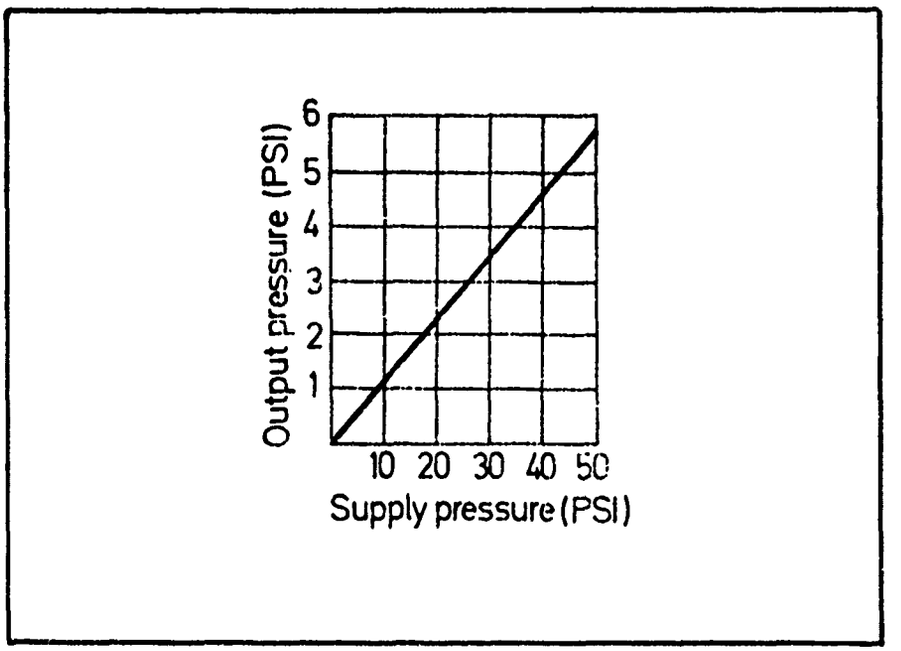


FIGURE 2.46 AVAILABLE DATA-INTERRUPTIBLE JET SENSOR-FESTO

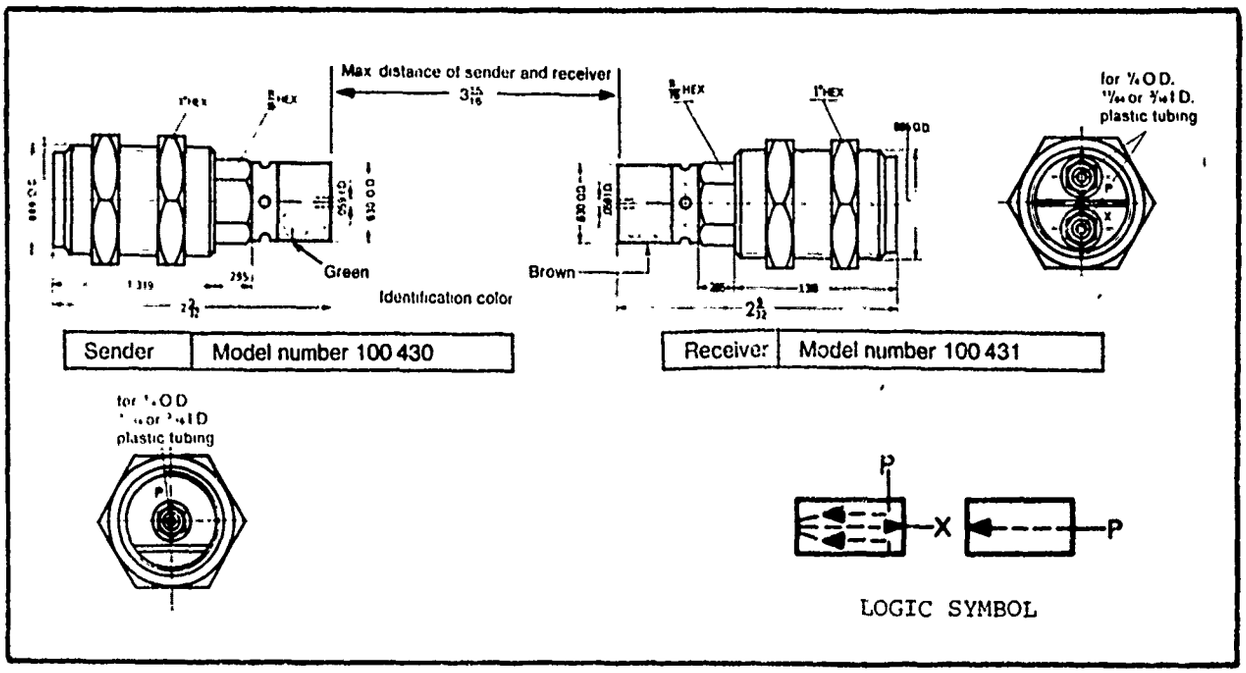


FIGURE 2.47 INTERRUPTIBLE JET-PROXIMITY SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Festo Brochure 1000-3

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: 55 psi Sender, 7 psi receiver

POWER SUPPLY FILTRATION: 25 micron, dry air

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Jintsink Drive, E.
Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $15.00 each Model 100430
$12.00 each Model 100431

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- U

OUTPUT: PRESSURE- U

IMPEDANCE: To operate FESTO Amplifier Model No. 007 089

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0 <GAP <4 inches MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Digital Pressure drop with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

GEOMETRIC PROPERTIES

1.	Iden#	SFL-100S	Dia. 0.9"	Lgth.	2-5/16"
2.	"	SFL-100F	Dia. 0.9"	Lgth.	2-5/16"
3.	"	SML-40S	Dia. 0.5"	Lgth.	1-5/16"
4.	"	SD-3	Dia. 0.5"	Lgth.	1-9/16"
5.	"	SFL-6	Dia. 0.5"	Lgth.	1-7/8"

NO FIGURE PROVIDED

NO LOGIC SYMBOL PROVIDED

FIGURE 2.48 INTERRUPTIBLE JET-AIR BARRIER SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Air Barrier

MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Festo Corporation

PRIMARY FLUID: Air

INTERFACE: Pressure Amplifier Provided

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron required

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive E.
Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: (Aug.76) $15.00 ea. Model SFL-100S $8.50 ea. Model SD-3
$12.00 ea. Model SFL-100F $13.00 ea. Model SFL-6
$5.25 ea. Model SML-40S

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 160 Hz TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: 1.5 psi Maximum: 3.5 psi

FLOW-Minimum: .320 scfm Model SFL-100S, SFL-100F

.040 scfm, Model SML-40S, SD-3, SFL-6

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0.025" to 4.0"* MINIMUM OBJECT SIZE: Unlimited

HYSTERESIS: U GAIN: NA

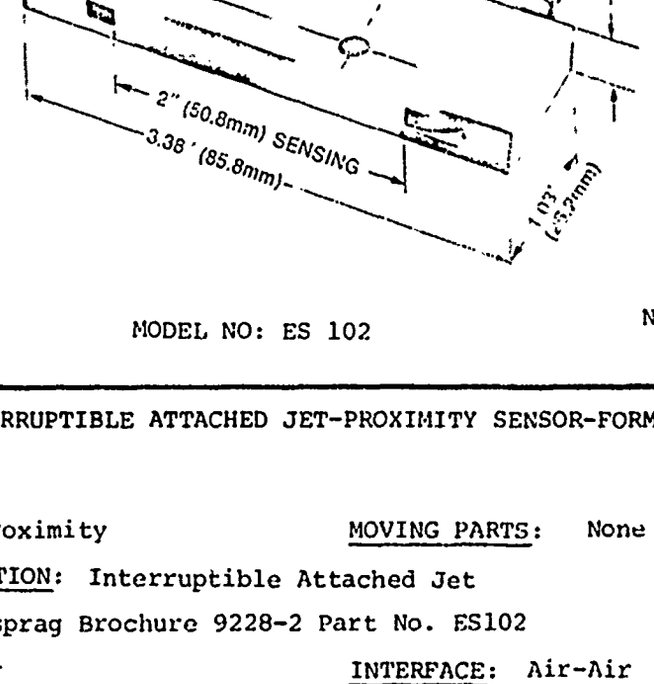
OUTPUT SIGNAL: Digital Pressure drop

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Depending upon Model size



MODEL NO: ES 102

NO LOGIC SYMBOL PROVIDED

FIGURE 2.49 INTERRUPTIBLE ATTACHED JET-PROXIMITY SENSOR-FORMSPRAG

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Attached Jet

DATA SOURCE: Formsprag Brochure 9228-2 Part No. ES102

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 350°F PRESSURE: U

POWER SUPPLY FILTRATION: 25 micron, oil free

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Formsprag Co., Division of Dana Corporation
P.O. Box 778, 26444 Groesbeck Hwy.
Warren, Michigan 48089

POINT OF CONTACT: (313) 758-5000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $43.50 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 30 Hz TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: 6 psig Maximum: 15 psig

FLOW-Minimum: 0.6 scfm Maximum: U

POWER-Minimum: U Maximum: U

OUTPUT: PRESSURE-Minimum: See Figure 2.50 .

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: 0.100 inch

OBJECT SENSING RANGE: to 1/8" in a 2" region interaction region MINIMUM OBJECT SIZE: .020"wire

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Digital pressure drop with object present.

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

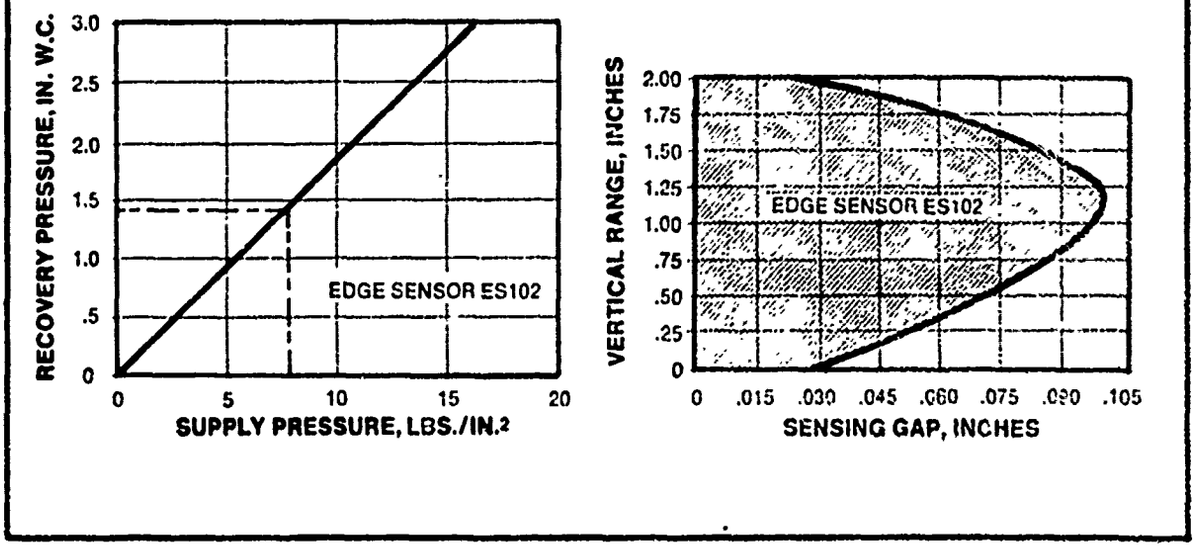
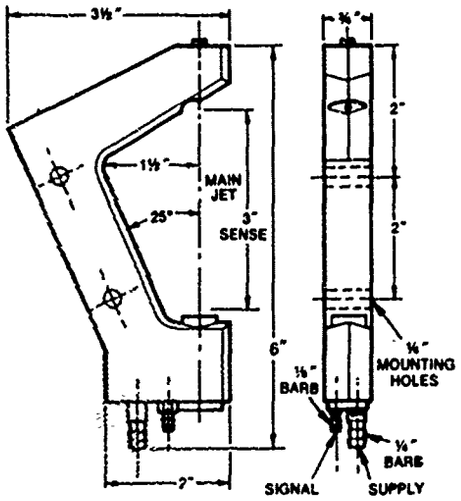


FIGURE 2.50 AVAILABLE DATA-INTERRUPTIBLE ATTACHED JET SENSOR-FORMSPRAG



NO LOGIC SYMBOL PROVIDED

MODEL NO: GS 333

FIGURE 2.51 INTERRUPTIBLE JET-PROXIMITY SENSOR-FORMSPRAG

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Formsprag Brochure X-3020: Part No. GS333

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 0° to 150°F, 0° to 300°F PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron, Oil free

EFFECT ON MEASURED QUANTITY: none

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Formsprag Co., Division of Dana Corp.
P.O. Box 778, 26444 Groesbeck Hwy.
Warren, Michigan 48089

POINT OF CONTACT: (313) 758-5000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $48.00 each

* With Teflon Tube

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 2 Hz TIME RESPONSE: 5 ms

SUPPLY: PRESSURE-Minimum: 6 psig Maximum: 20 psig

FLOW-Minimum: 0.6 scfm @ 10 psig

POWER-Minimum: U

OUTPUT: PRESSURE-Minimum: (Proportionate to supply; 0.25 psig at 10 psig supply)

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 20° from main stream nozzle. MINIMUM OBJECT SIZE: 0.25" radius

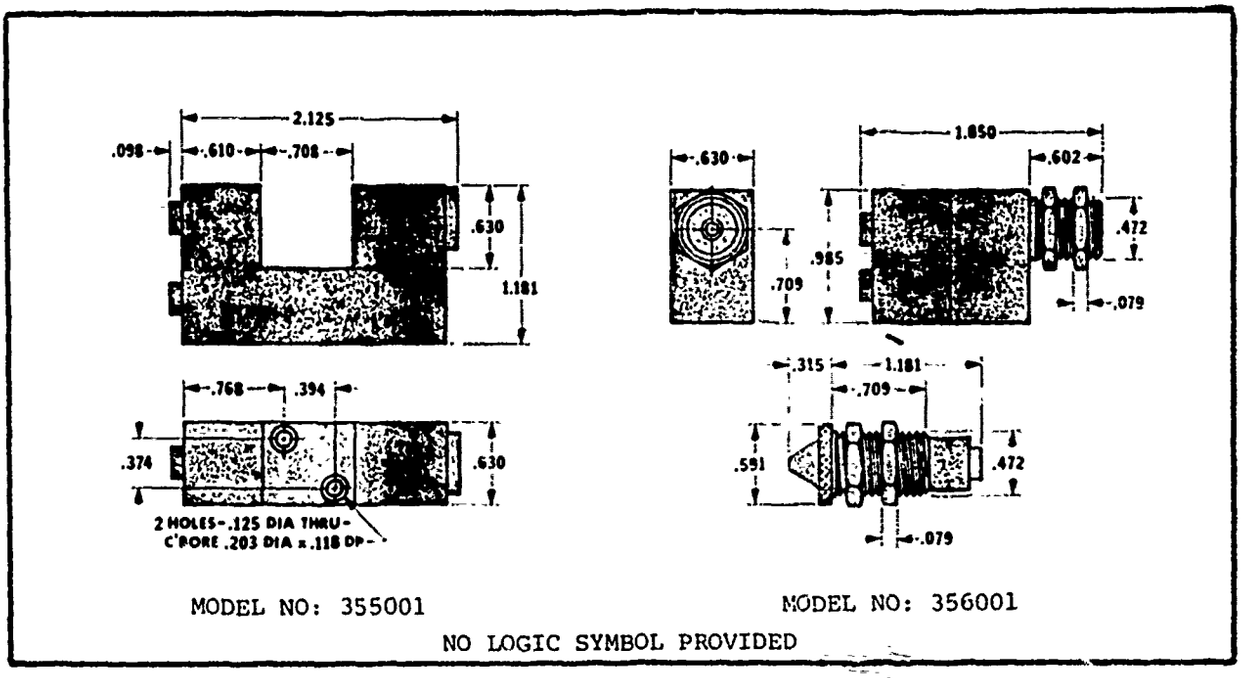
HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Digital pressure rise with object present

CROSS SENSITIVITY EFFECTS: May be sensitive to transverse motion

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



MODEL NO: 355001 MODEL NO: 356001

NO LOGIC SYMBOL PROVIDED

FIGURE 2.52 INTERRUPTIBLE JET-PROXIMITY SENSOR-MILLER FLUID POWER

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Miller Fluid Power Brochure, No. 5766-1275

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Miller Fluid Power
7N015 York Road
Bensenville, Illinois 60106

POINT OF CONTACT: (312) 766-3400

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

NOTE: Fixed gap sensor-Model 355001
Adjustable gap sensor-Model 356001

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: Part present, 50ms*
Part absent, 30ms

SUPPLY:	PRESSURE-Minimum:	45 psig	Maximum: 105 psig
	FLOW-Minimum:	U**	Maximum: U**
	POWER-Minimum:	U	Maximum: U
OUTPUT:	PRESSURE-Minimum:	U	Maximum: U
	FLOW-Minimum:	U	Maximum: U
	POWER-Minimum:	U	Maximum: U
CONTROL:	PRESSURE-Minimum:	NA	

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA

ACCURACY: U

OBJECT SENSING RANGE: 0" to 3.13"

MINIMUM OBJECT SIZE: .039" Flat
.078" Curved

HYSTERESIS: None

GAIN: NA

OUTPUT SIGNAL: Digital pressure drop with introduction of object

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Add 5ms for each 39" of 5/32 dia. tube connecting sensor to amplifier.
** Flow = 0.14 scfm at 75 psig.

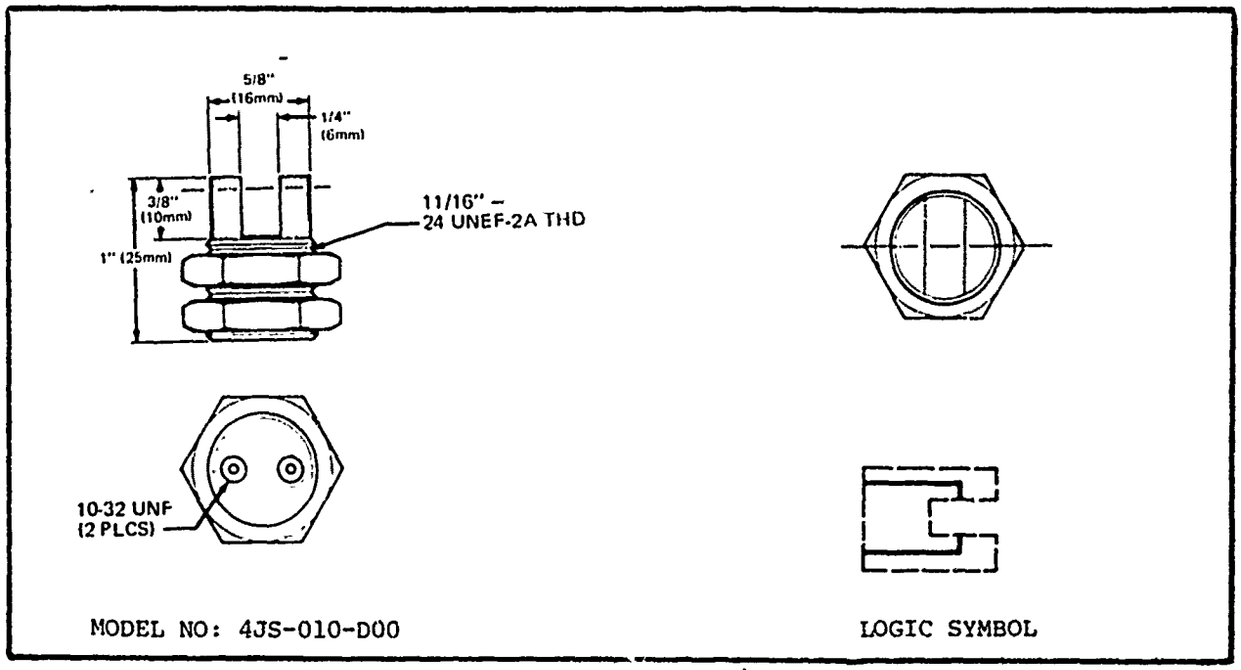


FIGURE 2.53 INTERRUPTIBLE JET-PROXIMITY SENSOR-NORGREN

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Norgren Brochure: Part No- 4JS-010-000

PRIMARY FLUID: Air INTERFACE: Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: C A Norgren Co.
5400 S. Delaware Street
Littleton, Colorado 80120

POINT OF CONTACT: Mr. Robert Peterson (303) 794-2611

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 10 psi nominal, Flow: 0.13 scfm nominal

OUTPUT: PRESSURE- 0.36 psi @ 10 psi supply

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0" to 0.25" MINIMUM OBJECT SIZE: U

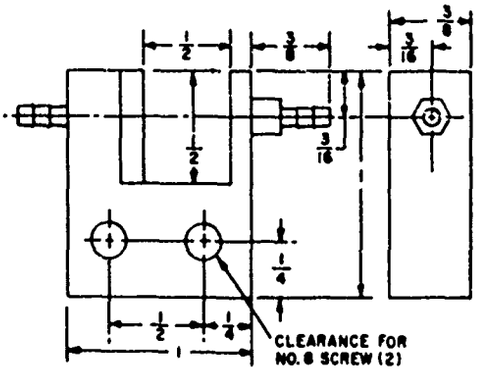
HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Digital pressure change

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



CR180DF50801C

FIGURE 2.54 INTERRUPTIBLE JET SENSOR - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: General Electric Brochure: Model# CR180DF50801C

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $6.30

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- To 5 psig

OUTPUT: PRESSURE- To 1.5 psig (See Figure 2.55)

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: See Figure 2.55 ACCURACY: U

OBJECT SENSING RANGE: 0.50 inch gap MINIMUM OBJECT SIZE: U

HYSTERESIS: None GAIN: NA

OUTPUT SIGNAL: Pressure drop with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: Unlimited

MTBF: U MCBF: U MTTR: U

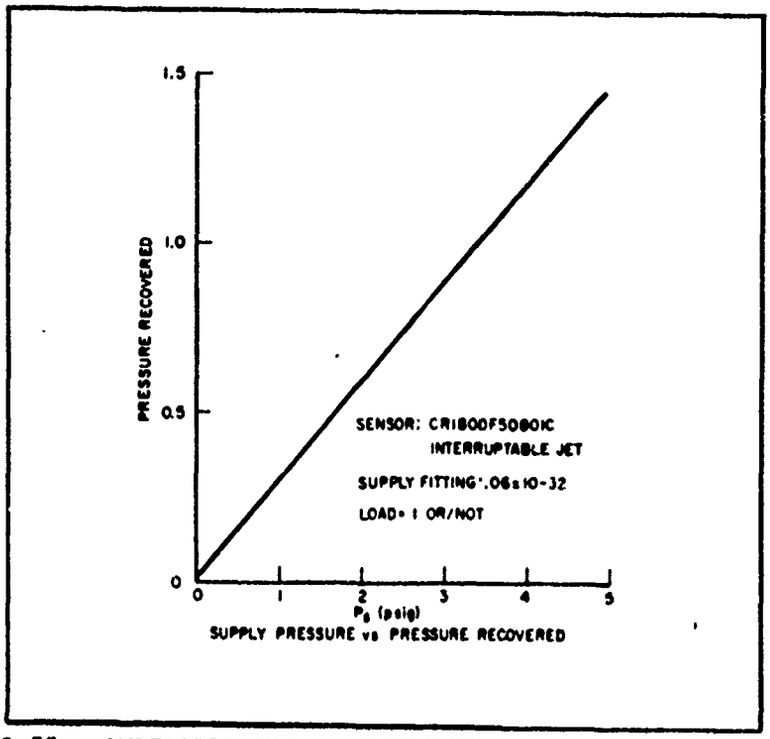


FIGURE 2.55 AVAILABLE DATA: INTERRUPTIBLE JET SENSOR - TRITEC, INC.

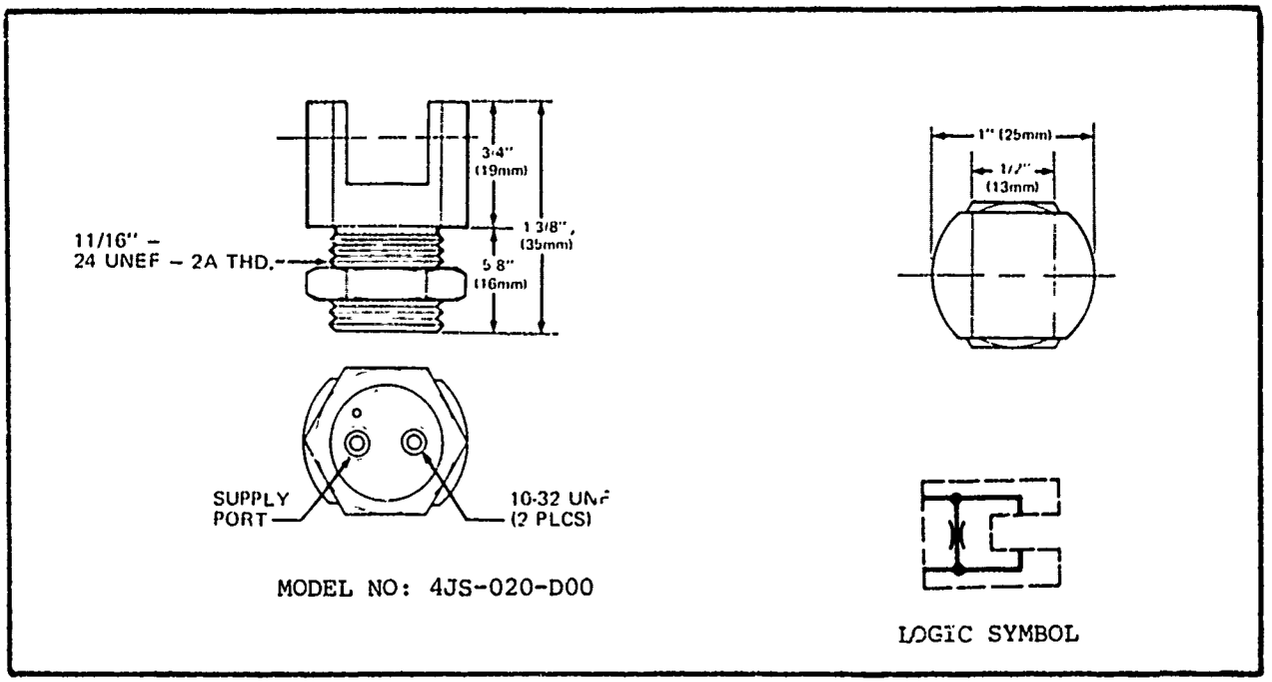


FIGURE 2.56 IMPACTING JET-PROXIMITY SENSOR-NORGREN

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Impacting jet

DATA SOURCE: Norgren Brochure Part No.-4JS-020-000

PRIMARY FLUID: Air

INTERFACE: Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: C A Norgren
5400 S. Delaware Street
Littleton, Colorado 80120

POINT OF CONTACT: Mr. Robert Peterson (303) 794-2611

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 10 psi nominal, Flow- 0.16 scfm nominal

OUTPUT: PRESSURE- 0.36 psi @ 10 psi

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

OBJECT SENSING RANGE: 0-0.5" MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Digital pressure change

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

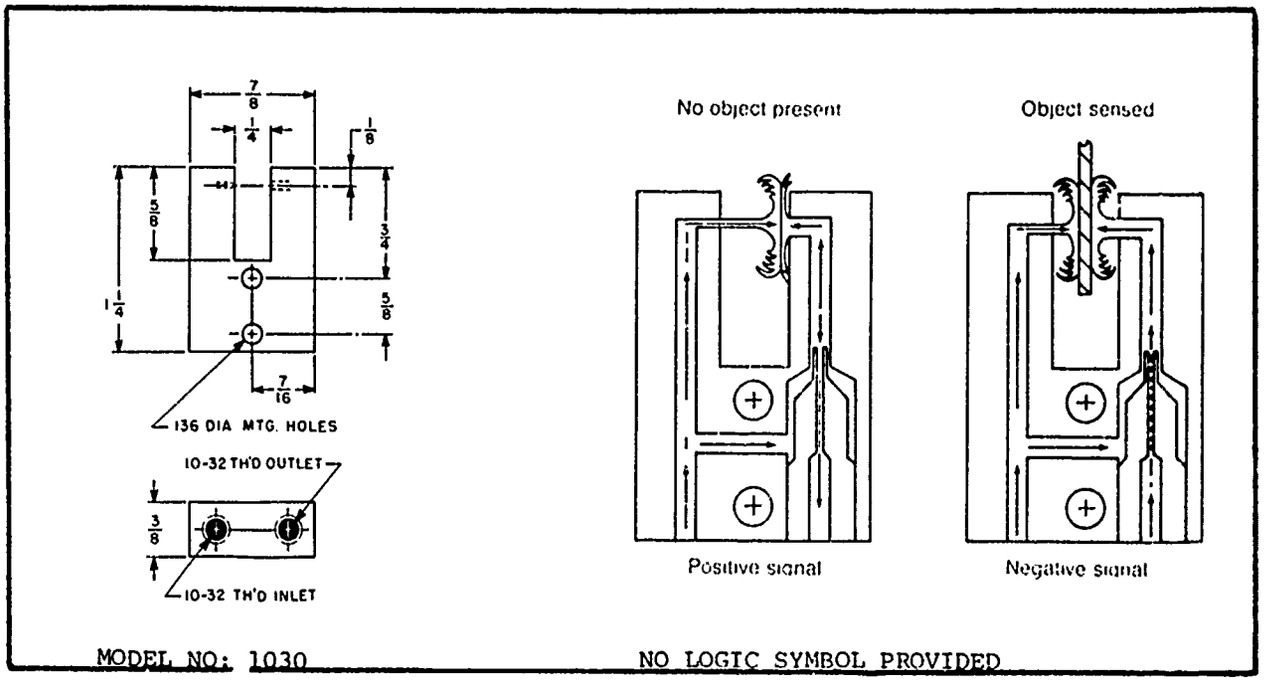


FIGURE 2.57 IMPACTING JET SENSOR - NORTHEAST FLUIDICS

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Interruptible Jet

DATA SOURCE: Northeast Fluidics Technical Sheet 1030

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -30 to 230°F PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Clippard Instrument Laboratory, Inc.
7390 Colerain Road
Cincinnati, Ohio 45230

POINT OF CONTACT: U (513) 521-4261

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 17 Hz

TIME RESPONSE: U

SUPPLY: PRESSURE- Minimum: 0.5 psig

Maximum: 5 psig

OUTPUT: PRESSURE- See Figure 2.58

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA

ACCURACY: U

OBJECT SENSING RANGE: 0.25 inch gap

MINIMUM OBJECT SIZE: .031" dia

HYSTERESIS: U

GAIN: NA

OUTPUT SIGNAL: Pressure drop with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA

EXPECTED LIFE: U

MTBF: U

MCBF: U

MTTR: U

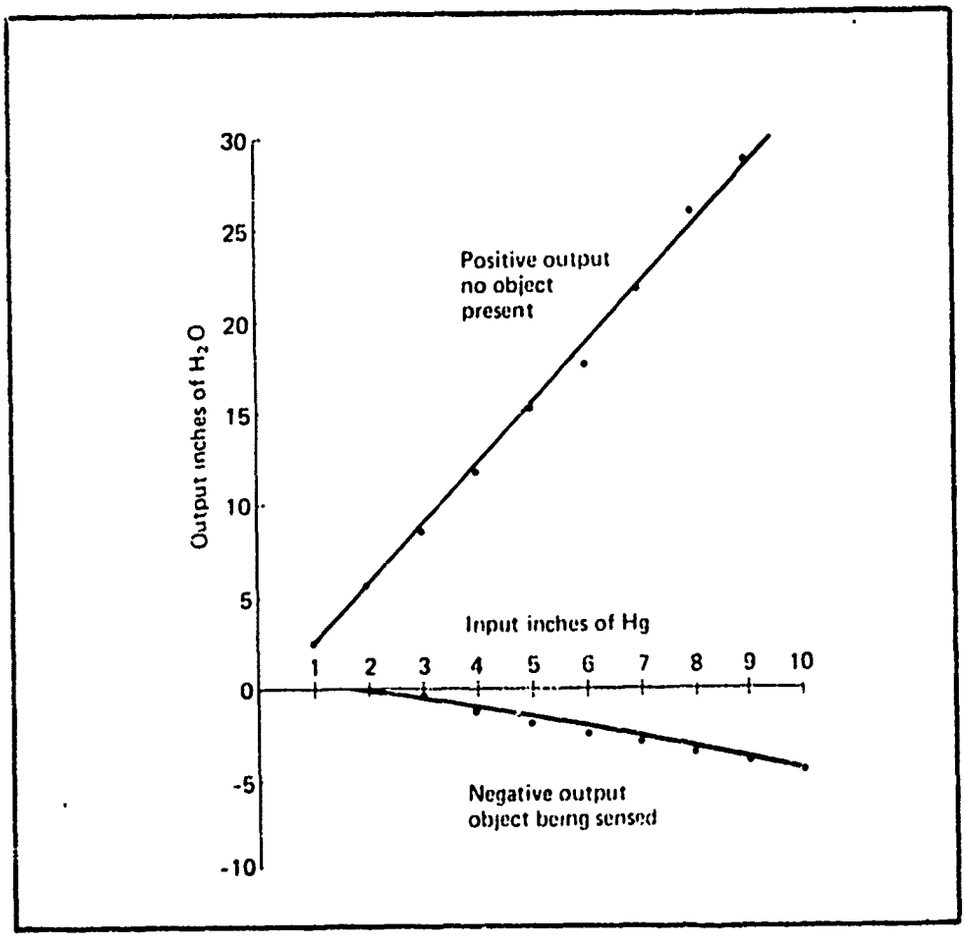


FIGURE 2.58 AVAILABLE DATA: IMPACTING JET SENSOR - NORTHEAST FLUIDICS

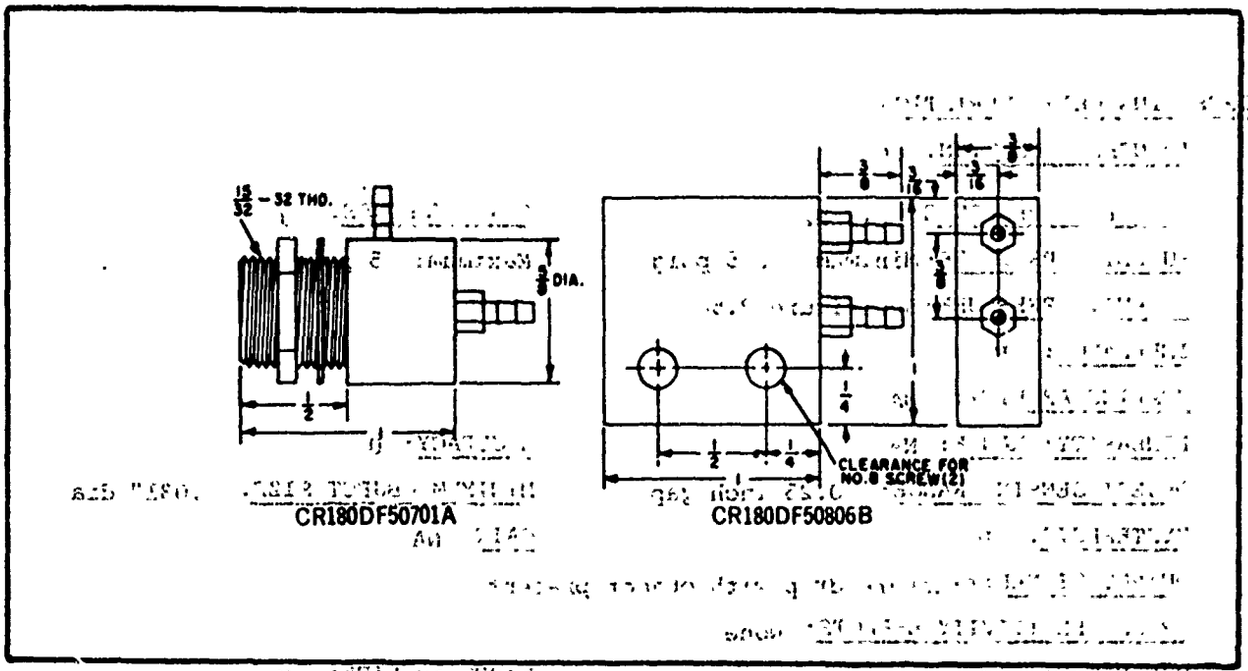


FIGURE 2.59 BACKPRESSURE PROXIMITY SENSOR - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Backpressure

DATA SOURCE: General Electric Brochure: Model #CR180DF50701A, #CR180DF50806B

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: To 100°C PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient Pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Off-the-Shelf

COST: Model #701A: $5.90
Model #806B: $5.20

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- To 5 psig

OUTPUT: PRESSURE- See Figure 2.60

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: See Figure 2.60

ACCURACY: U

OBJECT SENSING RANGE: To 0.016 inch

HYSTERESIS: NA

GAIN: NA

OUTPUT SIGNAL: Pressure or Flow

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: Unlimited

MTBF: U

MCBF: U

MTTR: U

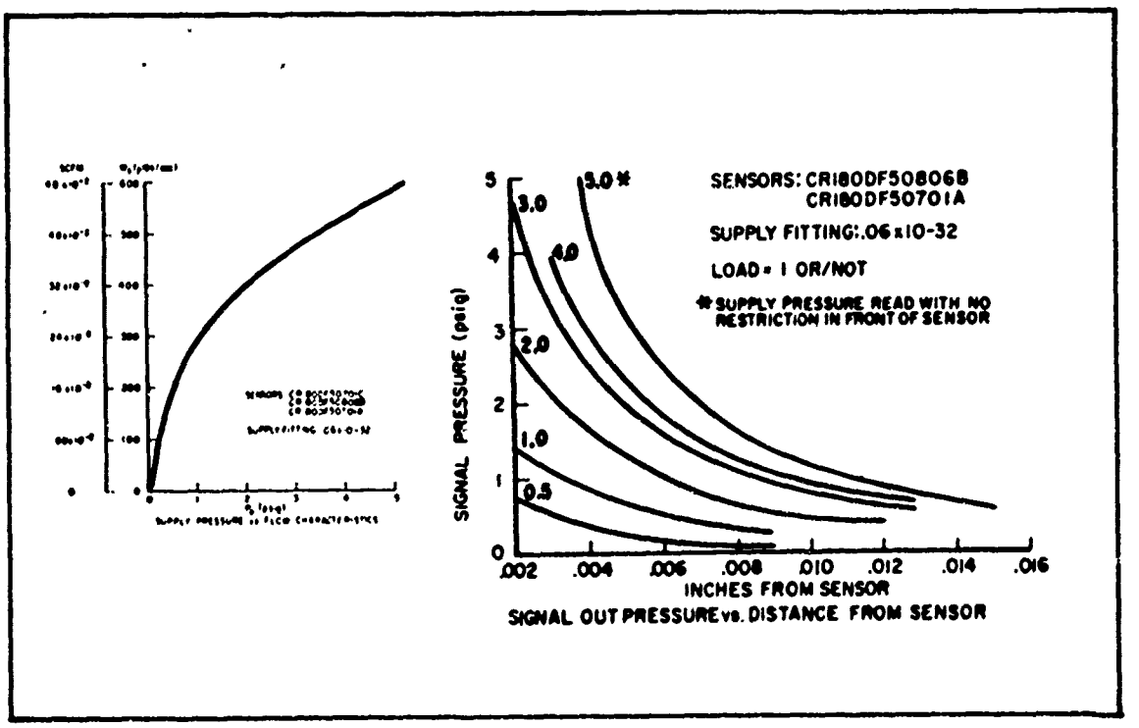
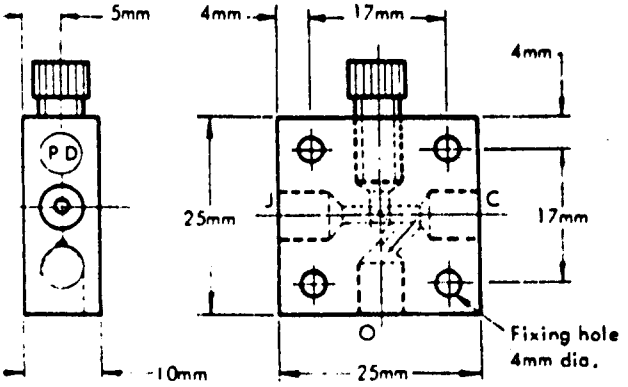


FIGURE 2.60 AVAILABLE DATA: BACKPRESSURE PROXIMITY SENSOR - TRITEC, INC.



NO LOGIC SYMBOL PROVIDED

FIGURE 2.61 BACKPRESSURE-PROXIMITY SENSOR-BRITISH FLUIDICS AND CONTROLS

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Backpressure

DATA SOURCE: British Fluidics and Controls Ltd.

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: to 100°C PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: British Fluidics and Controls Ltd.
Forest Road
Essex England

POINT OF CONTACT: Mr. N.W. Sykes

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.62

OUTPUT: PRESSURE- See Figure 2.62

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.62

ACCURACY: U

OBJECT SENSING RANGE: See Figure 2.62

MINIMUM OBJECT SIZE: U

HYSTERESIS: U

GAIN: U

OUTPUT SIGNAL: Proportional pressure

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: U

MTBF: U

MCBF: U

MTTR: U

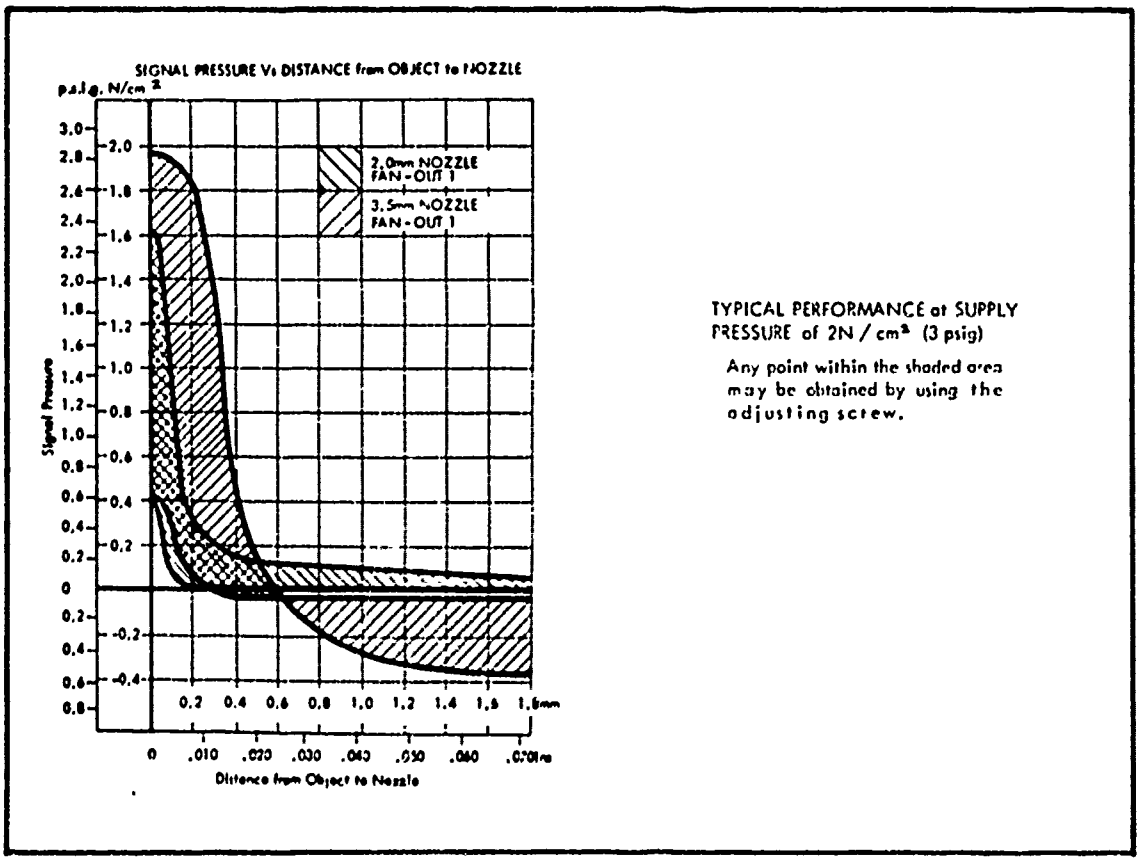


FIGURE 2.62 AVAILABLE DATA-BACKPRESSURE SENSOR-BRITISH FLUIDICS AND CONTROLS

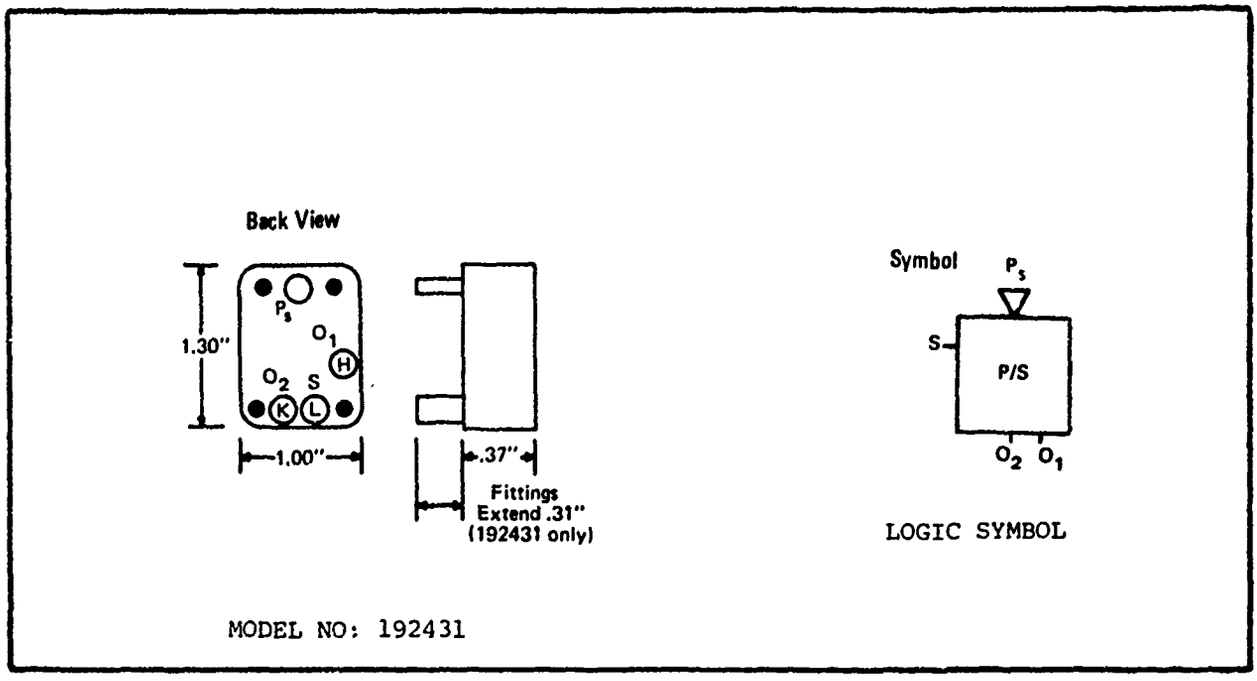


FIGURE 2.63 BACKPRESSURE FLUIDIC SWITCH-PROXIMITY SENSOR-CORNING

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Backpressure-fluidic switch

DATA SOURCE: Corning Fluidic Products Brochure: Part # 192431

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Corning Glass Works
Fluidic Products Department
Corning, N.Y. 14830

POINT OF CONTACT: William T. Greenfield Jr. (607) 974-8147

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $16.50 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: * See Table

SUPPLY: PRESSURE- See Figure 2.64

OUTPUT: PRESSURE- See Figure 2.64

IMPEDANCE: Fanout=1 for O_1; Fanout=4 with Corning manifold,=3 with tubing interconnection.

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to .010" MINIMUM OBJECT SIZE: .0625"x.0625"Flat

HYSTERESIS: 0" to .003" GAIN: NA

OUTPUT SIGNAL: Pressure rise

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* Response tests are performed using 5 psig supply pressure and a 10 foot length of 0.17in.inside diameter tubing between sensor and switch. A large, flat object is rapidly moved into/out of the sensing field in a direction perpendicular to the flow axis of the sensor. Response is measured at the output of the switch.

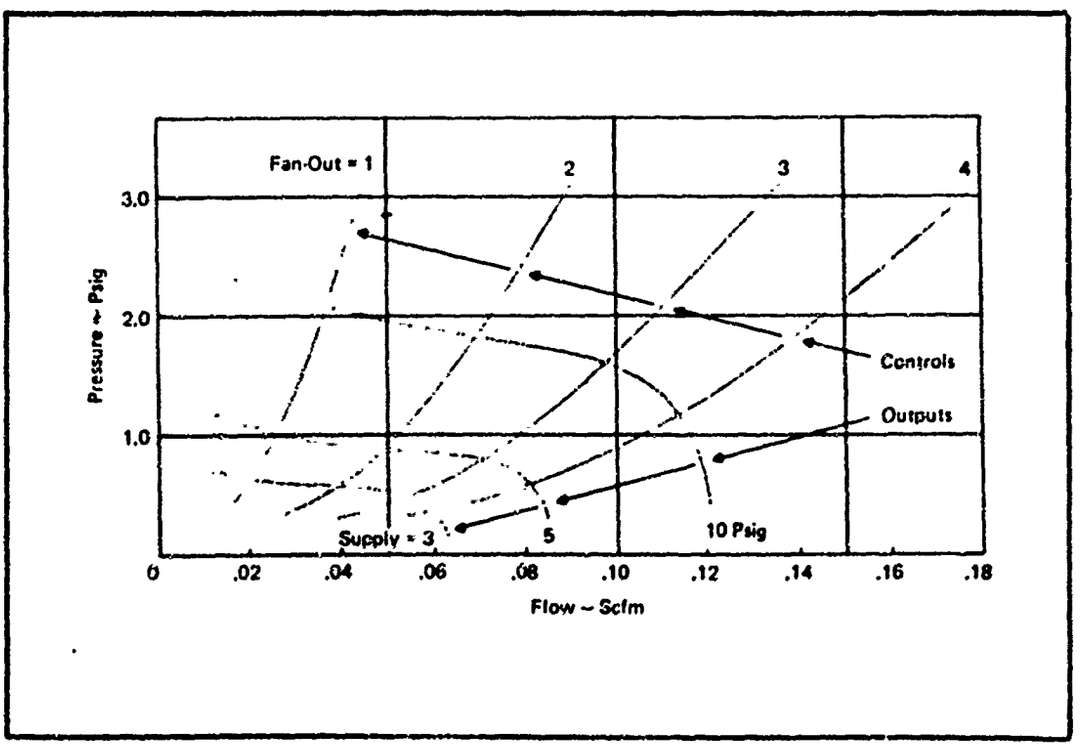
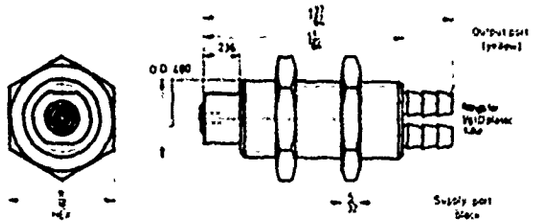


FIGURE 2.64 AVAILABLE DATA-BACKPRESSURE SENSOR-CORNING



MODEL NO: 004 498

LOGIC SYMBOL

FIGURE 2.65 BACKPRESSURE, ANNULAR NOZZLE-PROXIMITY SENSOR-FESTO

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Backpressure, Annular Nozzle

DATA SOURCE: Festo Brochure 5-3 Part No. 004498

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -40° to 212°F

PRESSURE: 120 psig

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Festo Corporation
10 Sintsink Drive E.
Port Washington, N.Y. 11050

POINT OF CONTACT: Mr. E. Fechner (516) 883-8571

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $8.50 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U			TIME RESPONSE: U	
SUPPLY: PRESSURE-Minimum:	1.5 psig		Maximum:	120 psig
FLOW-Minimum:	0.03 scfm		Maximum:	0.68 scfm
POWER-Minimum:	146.4 mw		Maximum:	266 watts
OUTPUT: PRESSURE-Minimum:	1.5 psig		Maximum:	120 psig
FLOW-Minimum:	0.03 scfm		Maximum:	0.68 scfm
POWER-Minimum:	U		Maximum:	U
CONTROL: PRESSURE-Minimum:	NA			

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: Contact MINIMUM OBJECT SIZE: U

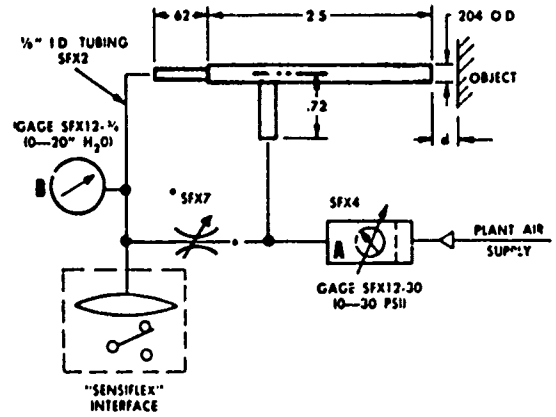
HYSTERESIS: ± 0.0002" GAIN: NA

OUTPUT SIGNAL: Pressure rise with presence of object

CROSS SENSITIVITY EFFECTS: NA

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



MODEL NO: SFX18

NO LOGIC SYMBOL PROVIDED

FIGURE 2.66 BACKPRESSURE-PROXIMITY SENSOR-GAGNE

GENERAL INFORMATION

TYPE OF SENSOR: Proximity

MOVING PARTS: None

PRINCIPLE OF OPERATION: Backpressure

DATA SOURCE: Gagne Information Bulletin: Part # SFX18

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Gagne Associates, Inc.
1080 Chenango Street
Binghamton, N.Y. 13901

POINT OF CONTACT: Mr. A. F. Gagne (607) 723-9556

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $9.85 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U			TIME RESPONSE:	U
SUPPLY:	PRESSURE-Minimum:	0 psig	Maximum:	30 psig
	FLOW-Minimum:	U	Maximum:	0.72 psig
	POWER-Minimum:	U	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	See Figure 2.67	Maximum:	U
	FLOW-Minimum:	U	Maximum:	U
	POWER-Minimum:	U	Maximum:	U
CONTROL:	PRESSURE-Minimum:	NA		

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: 0" to .25" MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

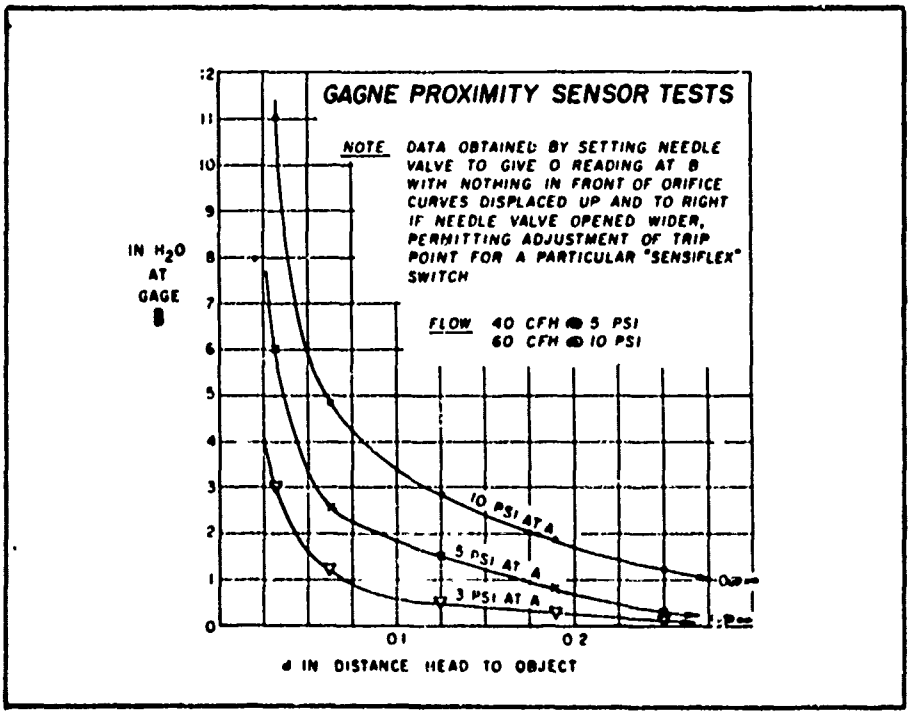


FIGURE 2.67 AVAILABLE DATA-BACKPRESSURE SENSOR-GAGNE

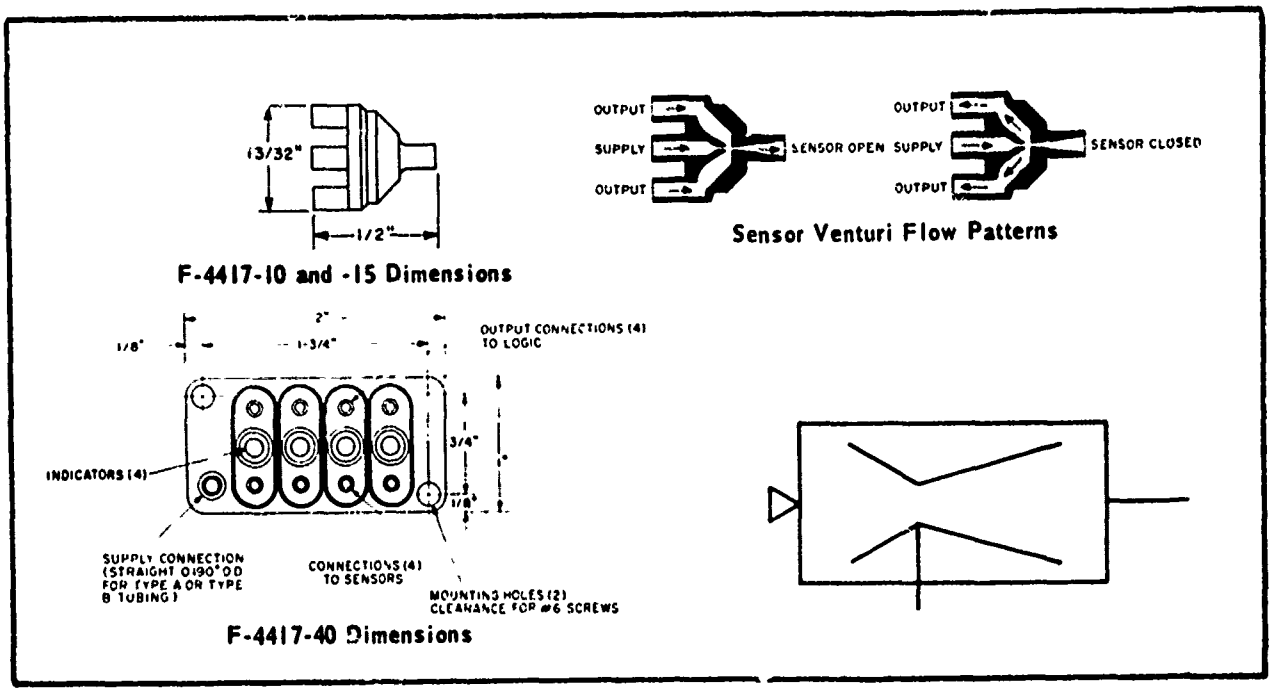


FIGURE 2.68 VENTURI, BACKPRESSURE-PROXIMITY SENSOR-AIR LOGIC

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: None

PRINCIPLE OF OPERATION: Venturi, Backpressure

DATA SOURCE: Air-Logic Brochure #8380 Part No. F-4417-10,-15,-40

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: $0 < T < 180^{\circ}F$ for -10&15 Models, $40^{\circ} < T < 120^{\circ}F$ for -40 Model

POWER SUPPLY FILTRATION: U PRESSURE: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Air Logic Division
Fred Knapp Engraving Co., Inc
5102 Douglas Avenue
Racine, Wisc. 53402

POINT OF CONTACT: Mr. Donald Kaske (414) 639-3941

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $4.35, package of 3 Models F-4417-10 and -15
$14.25, each F-4417-40

OPERATING CHARACTERISTICS

TRANSFFR FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: 2,0,0.5 Maximum: 20,3, 10 for Model #'s F-4417-10,F-4417-15 & F-4417-40 resp.

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

OUTPUT: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: U

POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: Fanout of 4

SCALING ABILITY: NA

LINEARITY: RANGE: NA ACCURACY: U

OBJECT SENSING RANGE: U MINIMUM OBJECT SIZE: U

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Pressure rise with object present

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

NOTE: Output sufficient to drive 4 Air-Logic F-3702-251 NOR logic elements at the same supply pressure.

2.2.5 Acoustic Proximity Sensor

The acoustic sensor (commonly referred to as the Fluidic Ear) is fluidic technology's counterpart of the photoelectric eye. Its principle is based upon the fact that the coherence of an air jet may be interrupted by a high frequency sound (typically in the order of 50 kHz). Basically, the fluidic ear contains two components, an emitter (or sender) and the receiver. The emitter projects the 50 kHz beam across the sensing gap, and the receiver (a digital/fluid amplifier) is interrupted by that acoustic beam. The separation between the sound emitter and receiver may be as large as 60 in. with response times as low as 2 ms. An additional advantage of this sensor over the simple interruptible jet is that the sound may be reflected so that the supply and the receiver need not be colinear. Thus, the unit may be designed to cover a rather large area. Manufacturers claim that by using interferrometric techniques, a resolution of displacement as small as 0.10 in. may be detected. It should be noted that the fluidic ear sensor is not affected by random frequencies (other than the narrow band near 50 kHz) and, thus is tolerant to vibration and shock over a wide range of temperatures and supply pressures. Two modes of operation are shown in Figure 2.69.

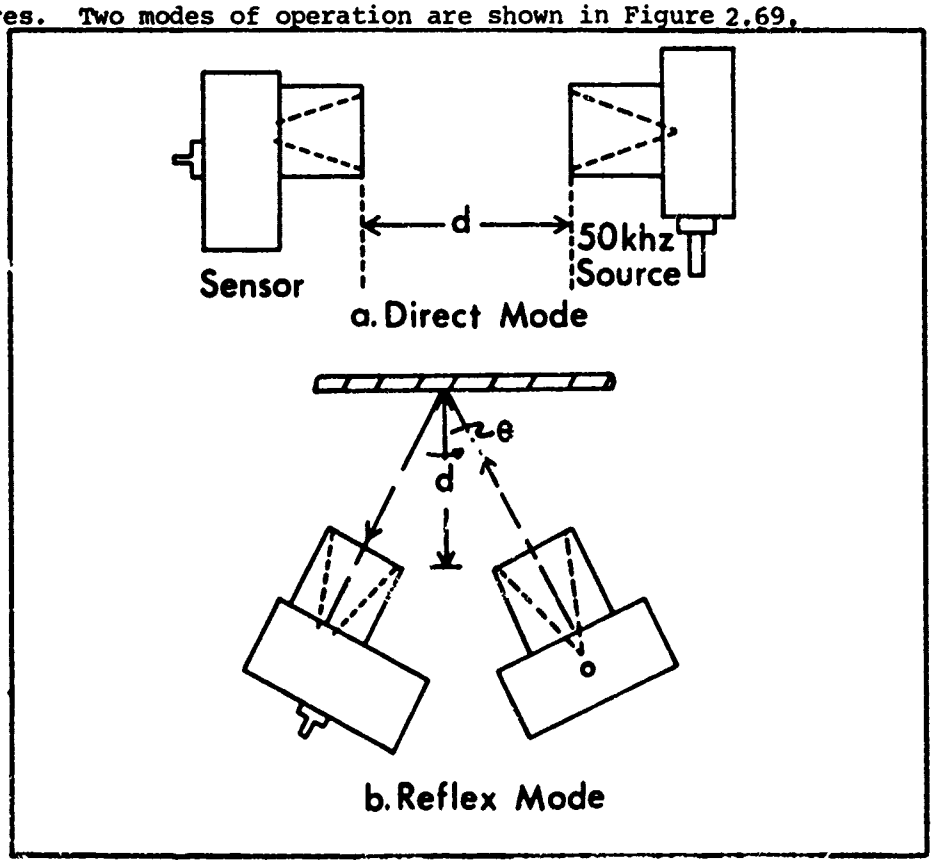


FIGURE 2.69 BASIC ACOUSTIC PROXIMITY SENSOR OPERATION

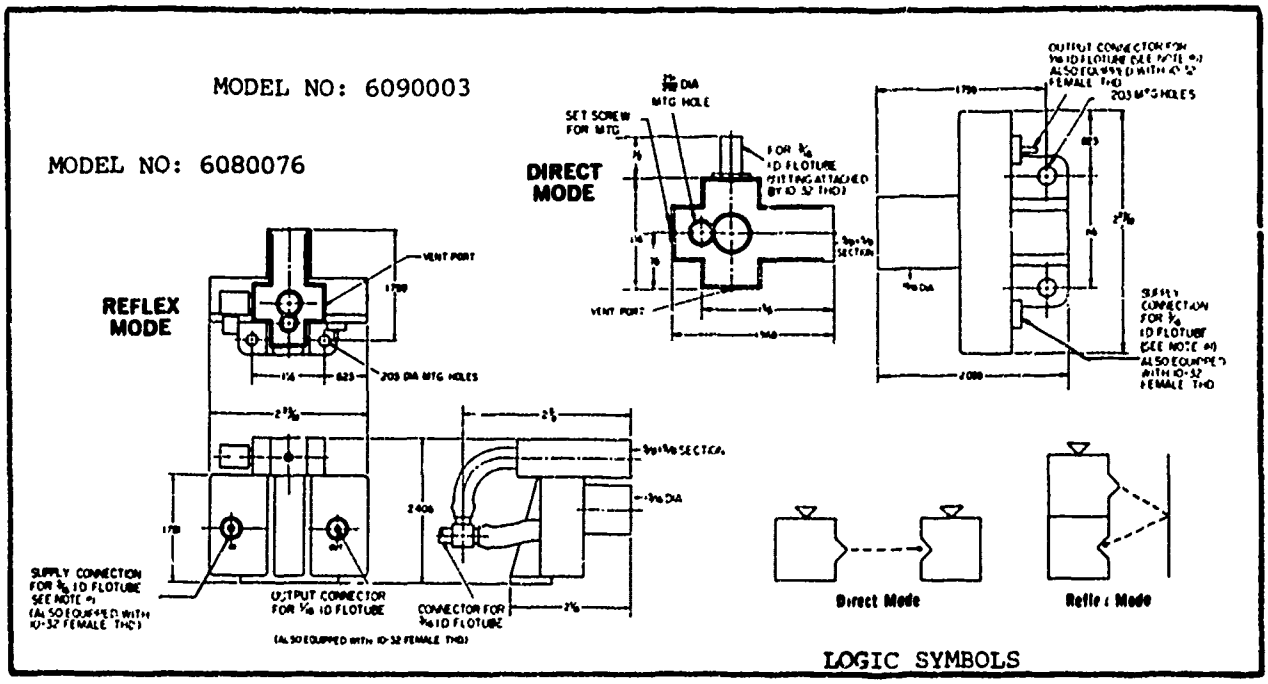


FIGURE 2.70 FLUIDIC EAR SENSOR-ASCO

GENERAL INFORMATION

TYPE OF SENSOR: Acoustic MOVING PARTS: None

PRINCIPLE OF OPERATION: Air generated 50 khz signal directed into receiver

DATA SOURCE: ASCO Brochure no. F901?

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 32° to 140°F PRESSURE: U

POWER SUPPLY FILTRATION: 1 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: 50 khz acoustic signal

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Automatic Switch Company
50-56 Hanover Road
Florham Park, N.J. 07932

POINT OF CONTACT: Mr. Edward E. Dorsey (201) 966-2000

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $ 55.00 Model # 6090003
$178.00 Model # 609A071

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 2 ms

SUPPLY: PRESSURE- See Figure 2.71

OUTPUT: PRESSURE- See Figure 2.71

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.71 ACCURACY: U

MAXIMUM SPAN: 5 ft. at 2.5 psig supply MINIMUM OBJECT SIZE: See Table Below

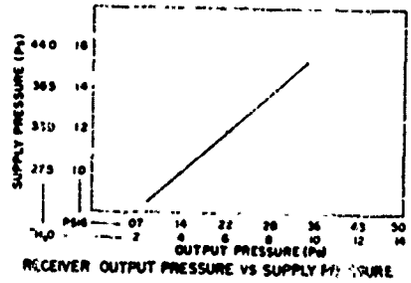
HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Digital pressure when beam is interrupted

CROSS SENSITIVITY EFFECTS: None

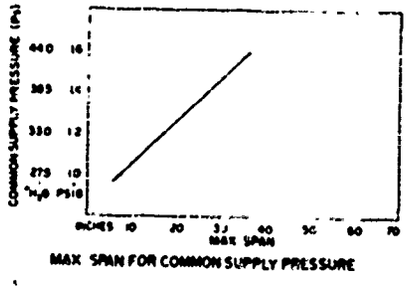
S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

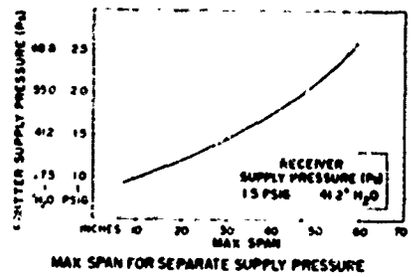


RECEIVER OUTPUT PRESSURE VS SUPPLY PRESSURE

Object Shape	Max. Sensing Distance
(2" x 2") plate	8"
½" diam. cyl.	1"
1" diam. cyl.	2"
2" diam. cyl.	4"
3" diam. cyl.	6"
4" diam. cyl.	7"



MAX SPAN FOR COMMON SUPPLY PRESSURE



MAX SPAN FOR SEPARATE SUPPLY PRESSURE

FIGURE 2.71 AVAILABLE DATA-FLUIDIC EAR SENSOR-ASCO

2.2.6 Hybrid Proximity Sensors

The application of any of the preceding components may be used in conjunction with several other types of fluidic devices to close ports, make electrical contacts, provide a force output, and/or effect an interface with another fluid. Several such hybrid proximity sensing devices are on the market. Some devices utilize a low force contact element such as a spring to provide a positive contact with the device being sensed. The output of this type of unit is much greater than any of the previously discussed purely fluidic elements and is usually analog. Since the output flow is directly proportional to the deflection of the spring, the curve of output signal vs force is usually linear.

Other variations of the basic device employ a fluidic sensor in consort with a diaphragm to convert the signal into either an electrical or a mechanical output. Several of these components are used in regions where it is impractical or unfeasible to employ fluidic staging elements to achieve the required signal amplification. A spring actuated device is shown in Figure 2.72.

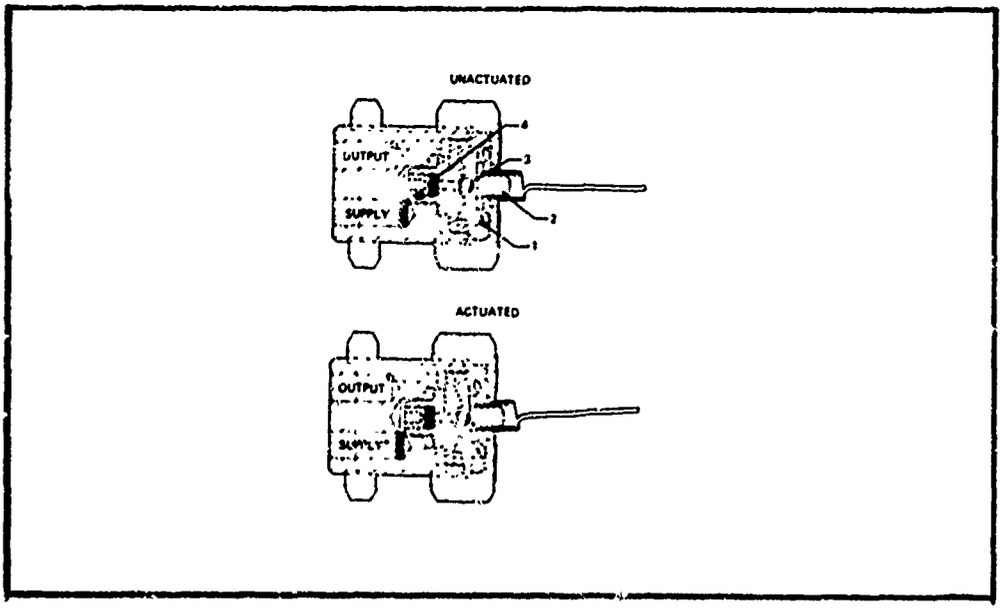
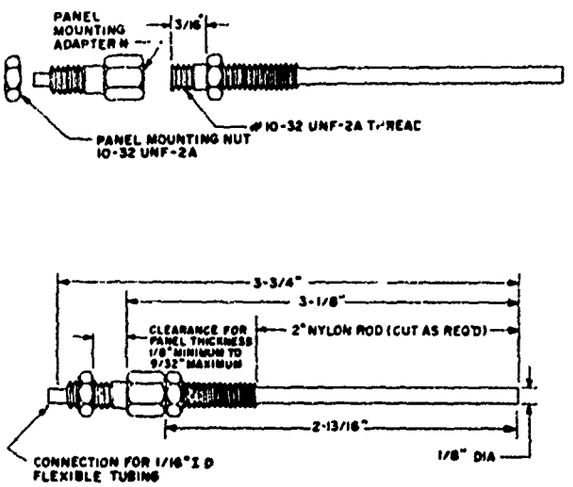


FIGURE 2.72 SPRING ACTUATED PROXIMITY SENSOR OPERATION



NO LOGIC SYMBOL PROVIDED

FIGURE 2.73 SPRING DEFLECTION-PROXIMITY SENSOR-AIR LOGIC

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: Spring Contact

PRINCIPLE OF OPERATION: Variable Bleed by Spring Deflection

DATA SOURCE: Air Logic Brochure #8370 Part No. F-4417-120

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 0^{o} to 150^{o}F PRESSURE: 30 psig

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: Physical contact required

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Air Logic Division
Fred Knapp Engraving Co., Inc.
5102 Douglas Avenue
Racine, Wisc. 53402

POINT OF CONTACT: Mr. Donald Kaske (414) 639-3941

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $9.75 package of 3

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.74

CONTROL FORCE: 1 oz. max. Deflection: 6° Min; 45° Max.

OUTPUT: PRESSURE- See Figure 2.74

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: See Figure 2.74

ACCURACY: U

OBJECT SENSING RANGE: U

MINIMUM OBJECT SIZE: U

HYSTERESIS: U

GAIN: U

OUTPUT SIGNAL: Proportional pressure drop

CROSS SENSITIVITY EFFECTS: Deflection in any direction

S/N RATIO: NA

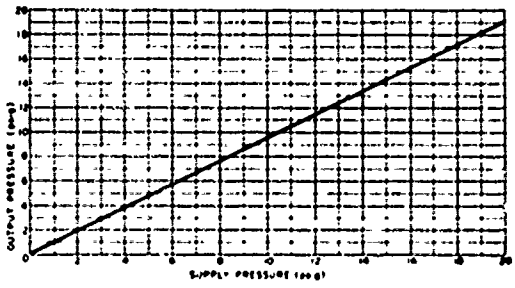
EXPECTED LIFE: U

MTBF: U

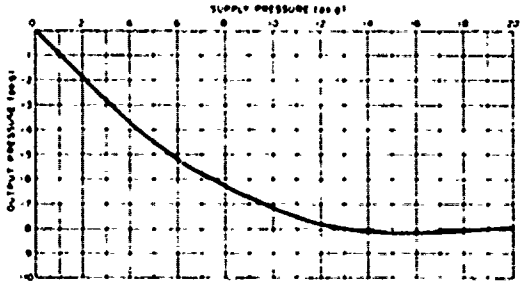
MCBF: U

MTTR: U

Typical F-4419-120 Application Using Sensor Venturi

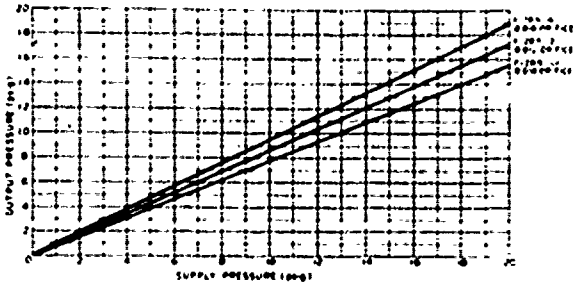


Typical F-4419-120 Output Pressure vs Supply Pressure with Spring Sensor Closed Using F-4417-10 Sensor Venturi.

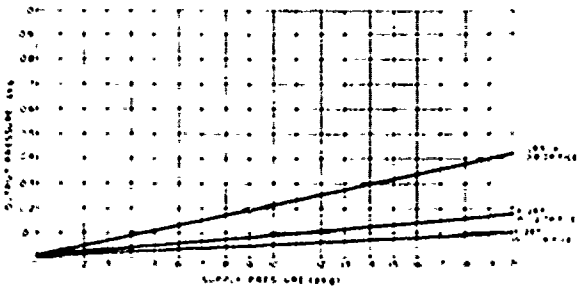


Typical F-4419-120 Output Pressure vs Supply Pressure with Spring Sensor Deflected 10° Using Sensor Venturi.

Typical F-4419-120 Application Using Upstream Orifice Restrictor



Typical F-4419-120 Output Pressure vs Supply Pressure with Spring Sensor Closed Using Different Size Supply Orifices.



Typical F-4419-120 Output Pressure vs Supply Pressure with Spring Sensor Deflected 10° Using Different Size Supply Orifices.

FIGURE 2.74 AVAILABLE DATA-SPRING DEFLECTION SENSOR-AIR LOGIC

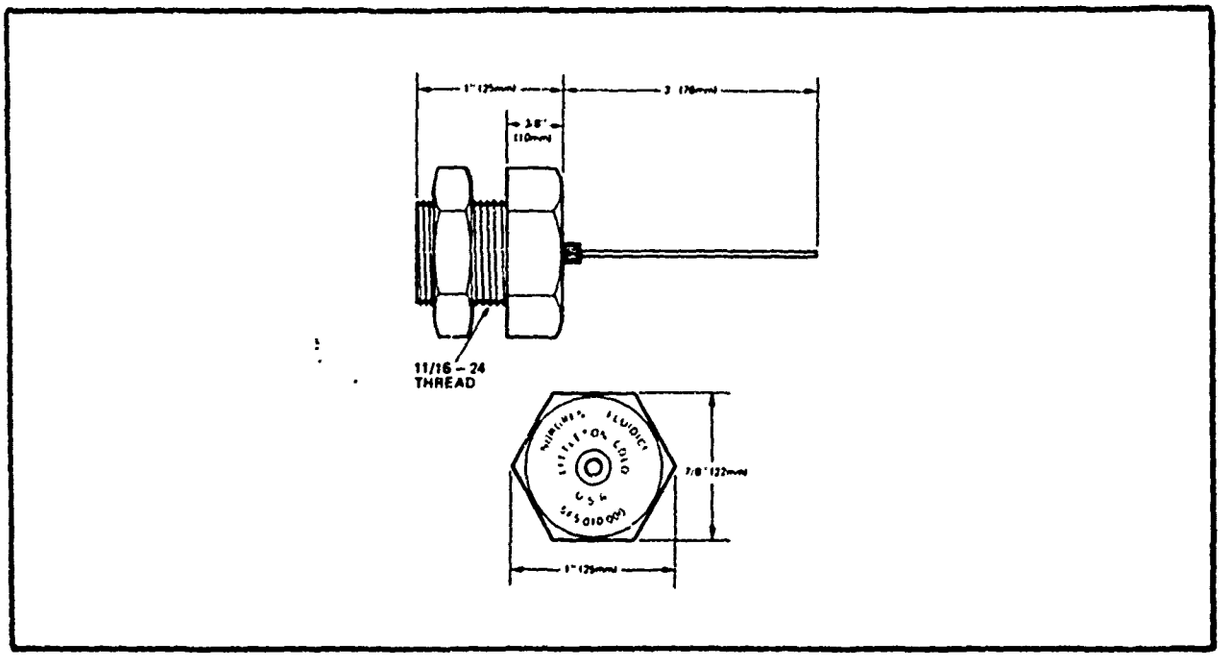


FIGURE 2.75 SPRING DEFLECTION-PROXIMITY SENSOR-NORGREN

GENERAL INFORMATION

TYPE OF SENSOR: Proximity MOVING PARTS: Spring Contact

PRINCIPLE OF OPERATION: Variable Bleed by Spring Deflection

DATA SOURCE: Norgren Brochure-Part # 5FS-010-000

PRIMARY FLUID: Air INTERFACE: Mechanical

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 35^{o} to 150^{o}F PRESSURE: 30 psig

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: Physical contact required

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: C A Norgren Co.
5400 W. Delaware Street
Littleton, Colorado 80120

POINT OF CONTACT: Mr. Robert Peterson (303) 794-2611

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY:	PRESSURE-Minimum:	10 psi	Maximum:	30 psi
	FLOW-Minimum:	.05 scfm	Maximum:	U
	POWER-Minimum:	1.63 watts	Maximum:	U
OUTPUT:	PRESSURE-Minimum:	.02 psi/degree	Maximum:	U
	FLOW-Minimum:	U	Maximum:	U
	POWER-Minimum:	U	Maximum:	U

CONTROL FORCE: .01 in./oz. Torque, Max Deflection 20°

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U

ACCURACY: U

OBJECT SENSING RANGE: 3"

MINIMUM OBJECT SIZE: U

HYSTERESIS: U

GAIN: U

OUTPUT SIGNAL: Proportional pressure drop

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

2.3 Angular Rate Sensors

Angular rate sensors are devices which measure the speed of rotation of an object about its axis. In general, this speed of rotation is directly proportional to the output signal generated by the sensor. Typical applications include measurements of the speed of a shaft, the speed of a gear system, and the angular rate of pitch or yaw of a vehicle. In the former cases the sensor does not rotate, but measures the speed of rotation externally. In the latter case (vehicle motion), the sensor itself is part of the rotating system and can be configured as shown in Figure 2.76.

Most angular rate sensors are not available commercially as off-the-shelf components, but are usually offered by manufacturers as part of an overall system tailored to a specific application. As such, each of the components presented in the following section is pertinent to a special application and should not be construed as being universally applicable to any system requiring an angular rate sensing element.

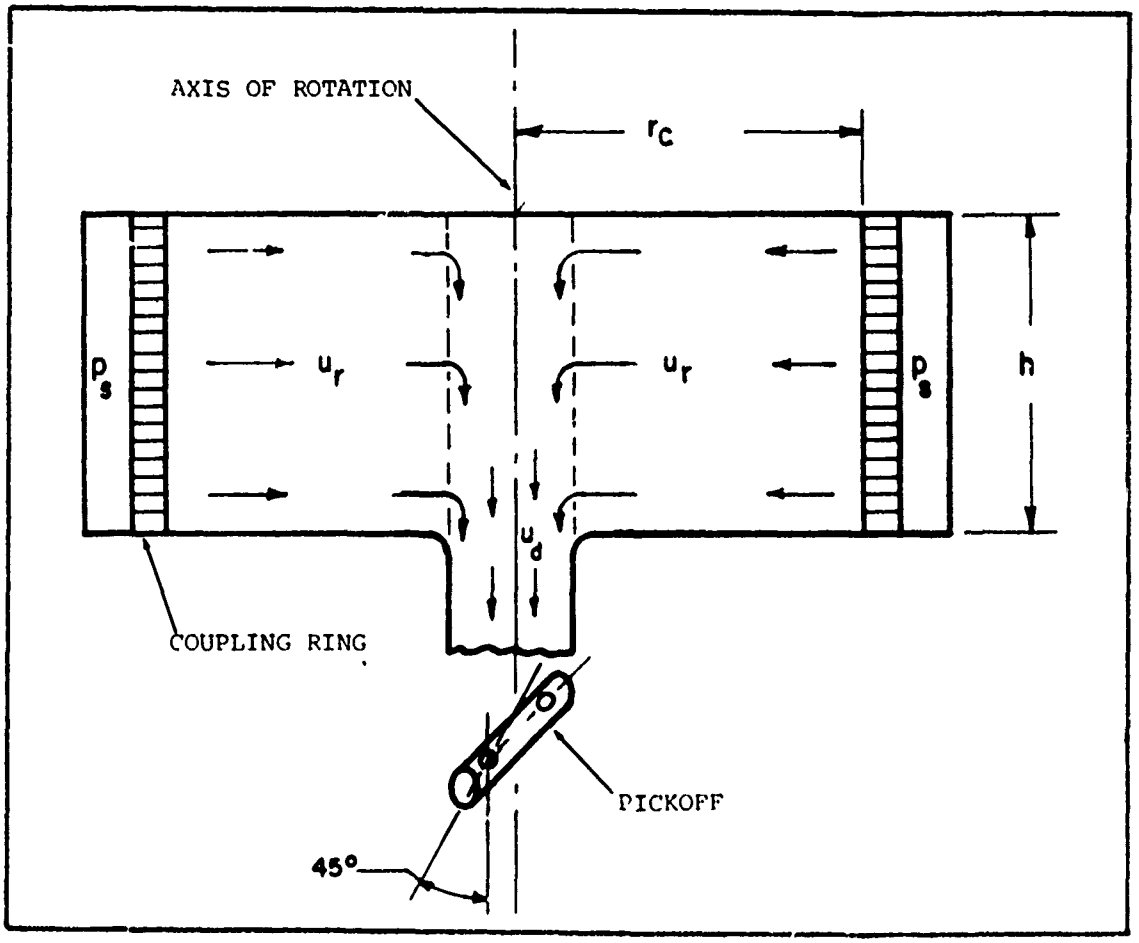


FIGURE 2.76 VORTEX ANGULAR RATE SENSOR SCHEMATIC

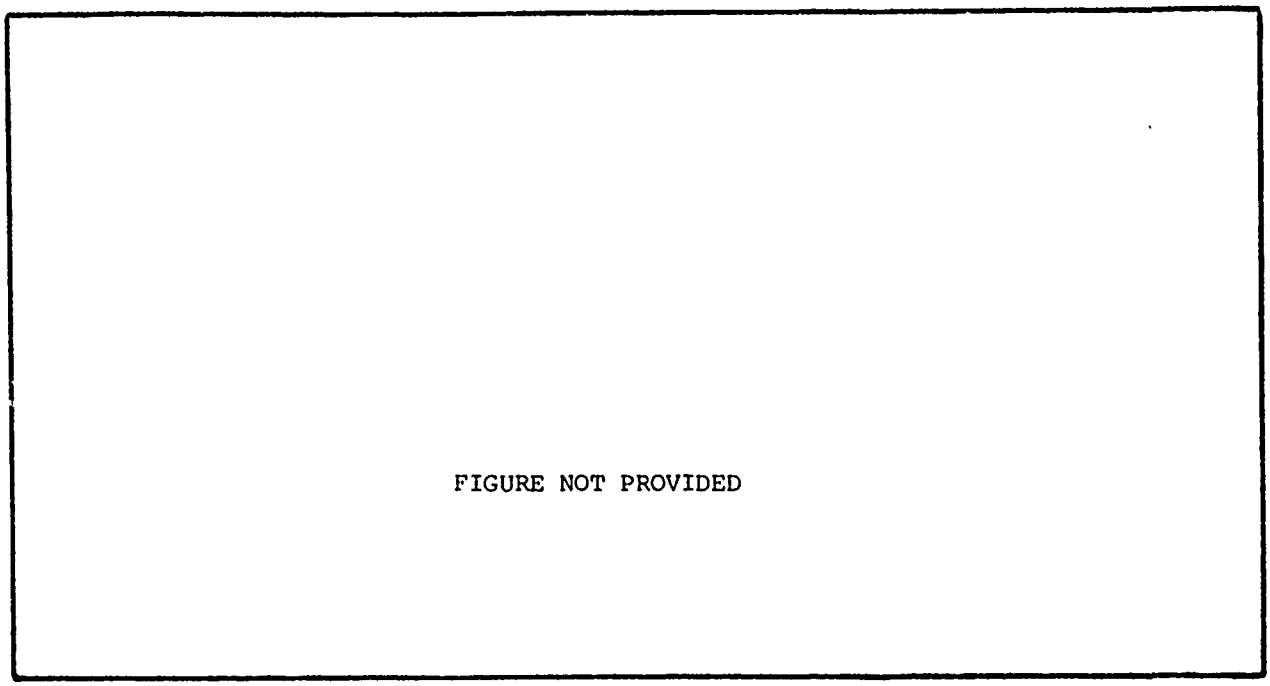


FIGURE 2.77 FREE JET ANGULAR RATE SENSOR

GENERAL INFORMATION

TYPE OF SENSOR: Angular Rate MOVING PARTS: None

PRINCIPLE OF OPERATION: Free jet impinging on collectors, entire device rotates

DATA SOURCE: See Point of Contact below

PRIMARY FLUID: Air, Liquid INTERFACE:

READOUT PROVIDED: No, Pressure gage required

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: None

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient or artificial pressure field

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Harry Diamond Laboratories
2800 Powder Mill Road
Adelphi, Maryland 20783

POINT OF CONTACT: Mr. Frank Manion (301) 394-3080

PRODUCT AVAILABILITY: R&D Device

COST: U

OPERATING CHARACTERISTICS *

TRANSFER FUNCTION: Time delay and simple lag

FREQUENCY RESPONSE: 50 Hz TIME RESPONSE: 3 ms

SUPPLY:	PRESSURE-Minimum:	1 psi (oil)	Maximum: 50 psi (oil)
	FLOW-Minimum:	0.05 gpm (oil)	Maximum: 0.3 gpm (oil)
	POWER-Minimum:	5 to 10 mw	Maximum: 3 w
OUTPUT:	PRESSURE-Minimum:	0	Maximum: 50% supply
	FLOW-Minimum:	0	Maximum: 50% supply
	POWER-Minimum:	0	Maximum: 20% supply

CONTROL: PRESSURE-Minimum:

IMPEDANCE: Output 50% supply

SCALING ABILITY: Yes, sensitivity, max. rate, bandwidth and flow consumption can be normalized.

LINEARITY: RANGE: Size dependent ACCURACY: Structure dependent

SENSING RANGE: Threshold .1 to .01% maximum saturation rate

HYSTERESIS: No GAIN:

OUTPUT SIGNAL: Pressure proportional to angular rate

CROSS SENSITIVITY EFFECTS: 1%

S/N RATIO: 1000 to 10000 EXPECTED LIFE: Indefinite

MTBF: U MCBF: U MTTR: U

* Operating characteristics are representative examples only since this is an experimental device.

2.3.1 Impulse Angular Rate Sensor

This type of sensor is based upon the principle of employing an interruptible jet to sense the separation between an emitter and the receiver as the jet is fragmented by a gear or other segmented wheel. This concept is shown in Figure 2.78. As the wheel rotates, the jet is interrupted continually, forming a pulse train whose frequency is linearly related to the shaft RPM. Care must be taken when designing such a system to ensure that the pulse train frequency is such that for a given rotational speed, the receiver or the interruptible jet sensor is not saturated (i.e., frequencies so high that the impulses are not easily discernible, but appear merely as a ripple on a DC steady state signal output). Virtually any of the interruptible jet sensors presented in Section 2.2.4 of this report can be used in conjunction with a gear to form an impulse type angular rate sensor. Note, the boundary layer type of angular rate sensor shown in Figure 2.78 operates on the same principle; however, no commercial devices exist which employ this principle.

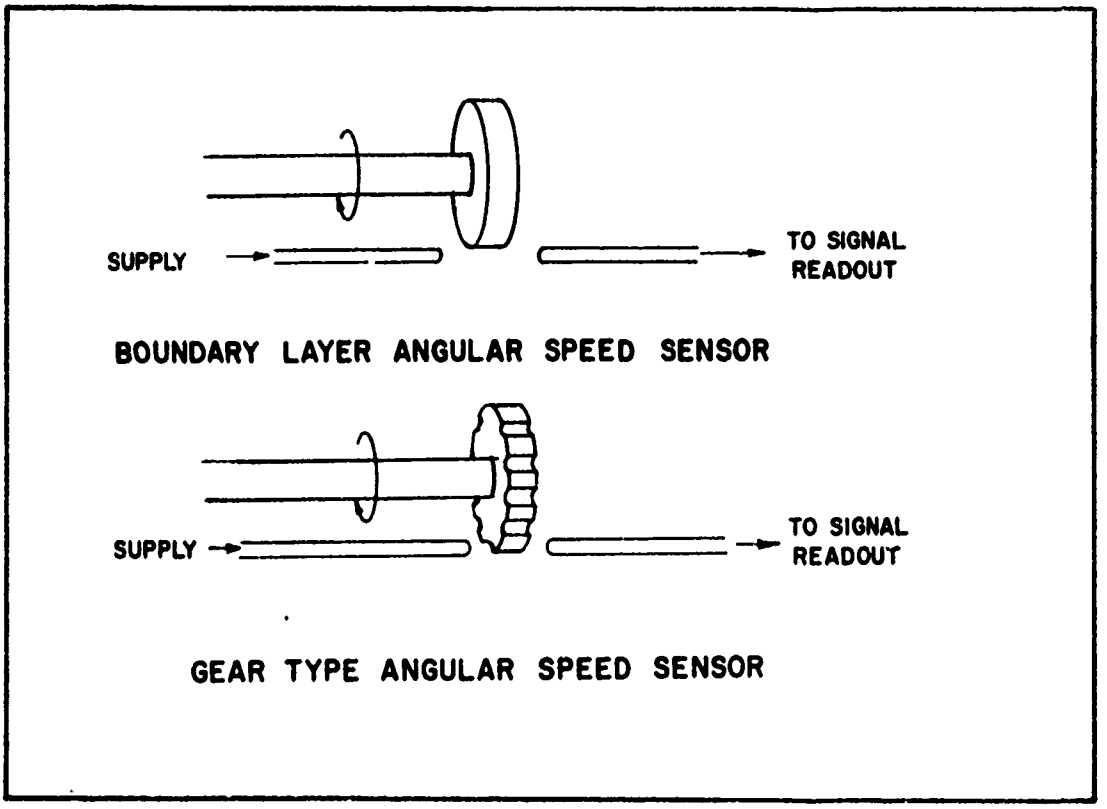


FIGURE 2.78 BASIC SHAFT RATE SENSOR OPERATION

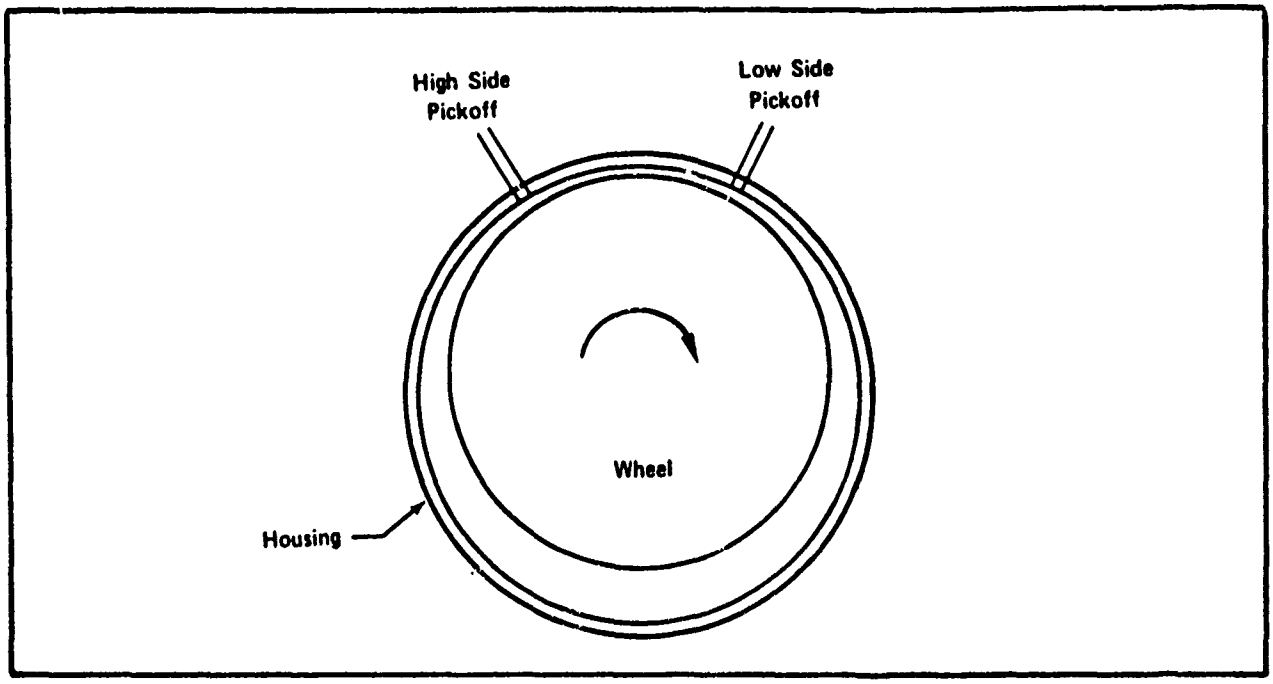


FIGURE 2.79 PROPORTIONAL SHAFT RATE SENSOR - HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Proportional Speed Sensor MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Hydrodynamic journal used to create pressure

DATA SOURCE: Honeywell: Fluidic Sensors Handbook

PRIMARY FLUID: Air/Oil INTERFACE: None

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -20° to 300°F PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: Tested to 10 g's @ 2000 Hz

REFERENCE: U

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell, Inc.
2600 Ridgway Parkway
Minneapolis, Minn. 55413

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- As required

OUTPUT: PRESSURE- See below*

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.80 ACCURACY: ± 0.5%

SENSING RANGE: 2,000 to 20,000 RPM

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Pneumatic

CROSS SENSITIVITY EFFECTS: Some temperature effects

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* $\Delta P = 0.00.42 \frac{\mu N}{(h/Rw)^2}$

where:

ΔP = Pressure output

μ = Dynamic viscosity

N = RPM

Rw = Rotor radius

h = Minimum clearance between rotor and probe

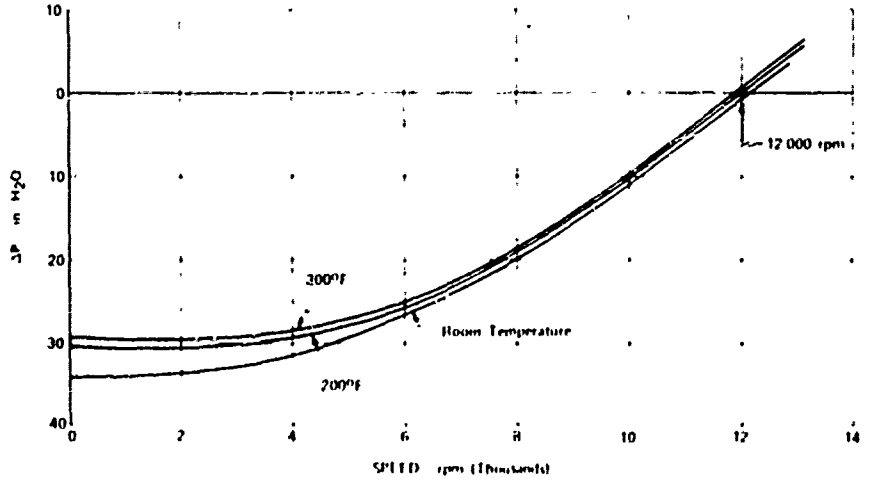


FIGURE 2.80 AVAILABLE DATA: PROPORTIONAL SHAFT RATE SENSOR - HONEYWELL

2.3.2 Vortex Angular Rate Sensor

The vortex angular rate sensor is based on the principle of conservation of angular momentum. It has a geometry similar to that shown in Figure 2.73 and is particularly useful when the angular rate to be sensed is small or the range of the rate to be sensed is extremely large. As shown, fluid enters the device tangentially, thus creating an initial fluid rotation through the vortex chamber prior to flowing out of the drain. Any angular rotation about the axis of the device is "added" to the tangential component of the flow thereby inducing a larger or smaller vortex depending upon the direction of body rotation relative to the initial vortex generated in the device. The sensitivity of this device is highly dependent upon the pickoff type, number, and construction, and although it has probably undergone more development than any other type of sensor, problems still include drift and hysteresis. Claims for sensitivities range from a threshold of 1/10 of a degree per second to a full scale range of 3000 degrees per second.

A variation of the device based upon laminar flow has been developed in an attempt to improve signal to noise ratio characteristics. Unfortunately, no devices of this type are commercially available as off-the-shelf components. However, several have been developed as specialized items for specific system application.

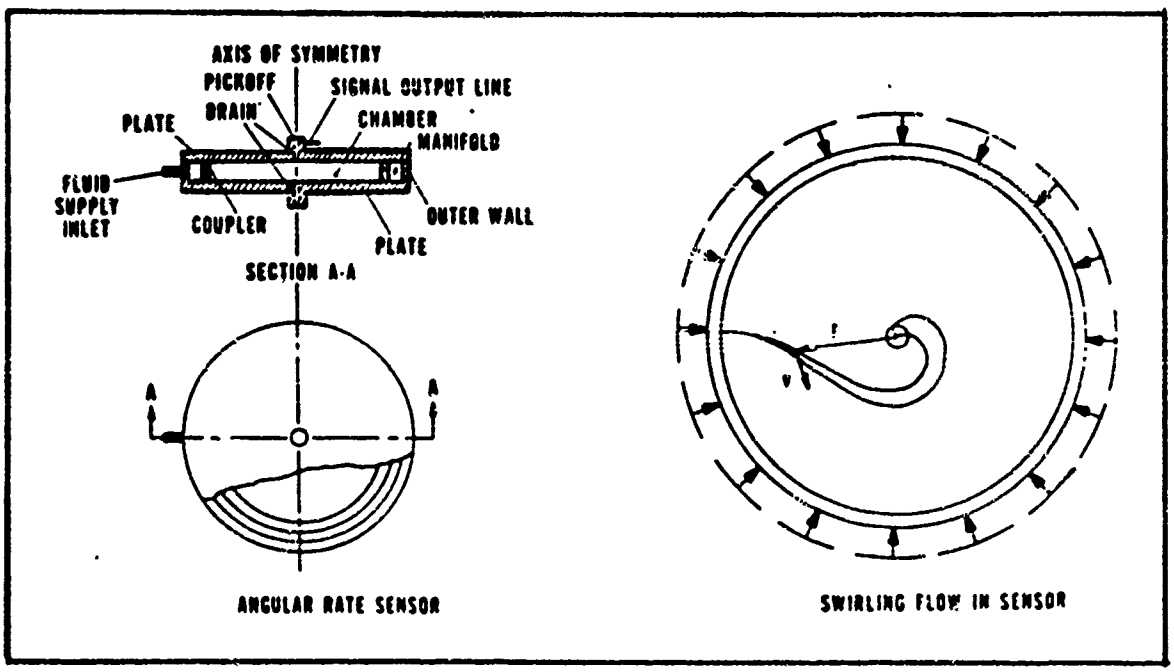


FIGURE 2.81 BASIC VORTEX ANGULAR RATE SENSOR OPERATION

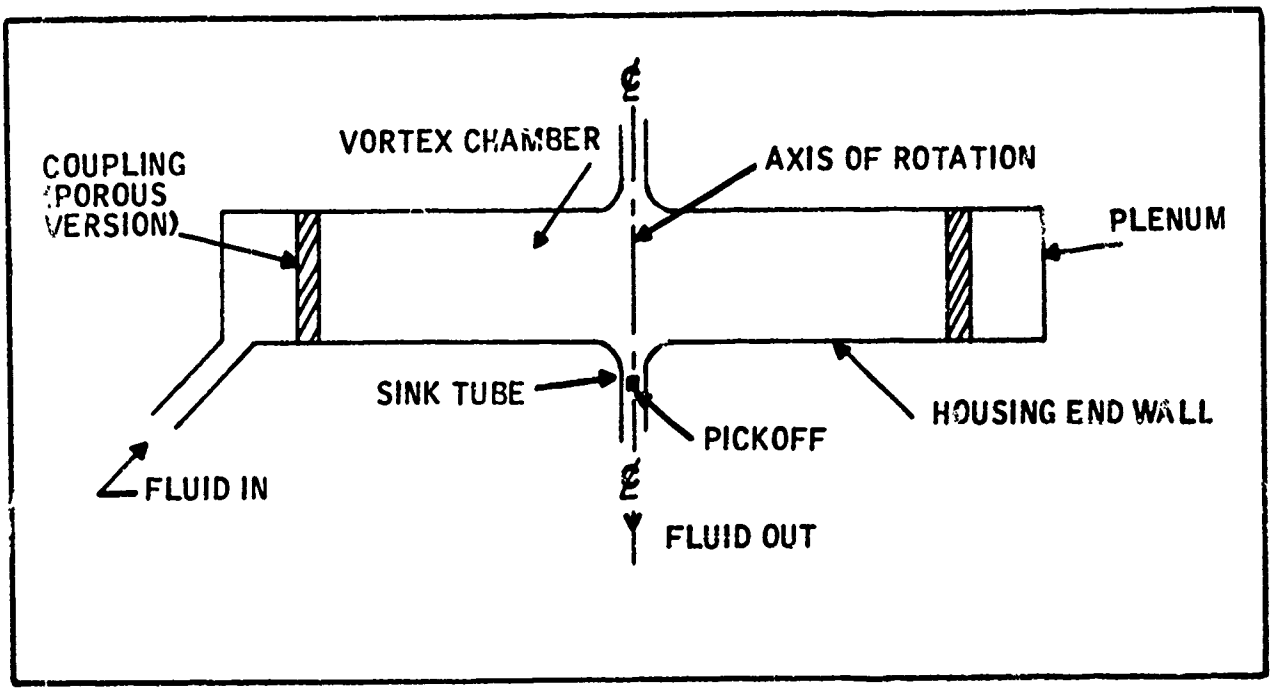


FIGURE 2.82 VORTEX ANGULAR RATE SENSOR-HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Angular Rate MOVING PARTS: None

PRINCIPLE OF OPERATION: Helical Flow in Vortex drain sensed by a pickoff.

DATA SOURCE: Honeywell Inc.

PRIMARY FLUID: Air,Water, Hydraulic Oil INTERFACE: Fluidic

READOUT PROVIDED: Pressure Transducer required

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 40° to 240°F PRESSURE: Altitude limited

POWER SUPPLY FILTRATION: 10 micron required

EFFECT ON MEASURED QUANTITY: No

SENSITIVITY TO:

SHOCK: No NOISE: No

ACCELERATION: Depends on axis VIBRATION: No

REFERENCE: 40 psia pressure signal

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell Inc.
1625 Fartham Ave.
Minneapolis, Minn. 55416

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Special Order Only

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $.005\ e^{-.0205}$ Psid/degree/sec

FREQUENCY RESPONSE: 12 Hz TIME RESPONSE: .020 sec time delay

SUPPLY: PRESSURE- 40 psid nominal, Flow: .069 scfm nominal

OUTPUT: PRESSURE-

IMPEDANCE: U

SCALING ABILITY: Yes, by changing sensor size and flow consumption

LINEARITY: RANGE: 100 degree/sec ACCURACY: 5% of reading

SENSING RANGE: < 0.25 deg/sec SATURATION, > 1000 deg/sec

HYSTERESIS: NA GAIN: .005 psid/deg/sec

OUTPUT SIGNAL: differential pressure NULL POINT: < ± 2 deg/sec

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: < 0.5 deg/sec EXPECTED LIFE: > 100,000 hrs.

MTBF: > 70,000 hrs MCBF: U MTTR: U

NOTE: Data are representative only

2.3.3 Hybrid Systems

For the purposes of this manual, hybrid systems are defined as those which employ either electrical or mechanical components in the system or some combination of the phenomena previously addressed by the other sensors. For example, the effect of Coriollis forces on a laminar jet has been used as the basis for a sensor having an electrical pickoff. Thermistors connected to a bridge circuit cause a jet to deflect proportional to the rotation of the unit. The flow of the laminar jet is generated by oscillations of a Piezoelectric crystal making the unit totally independent of an external air supply. Manufacturer claims for this system are that the output is extremely linear and that the unit can withstand shocks in excess of 1000 G's. However, because of its geometry, it appears that it may be responsive to linear accelerations along the axis of the pumping element. A representative unit is shown in Figure 2.83.

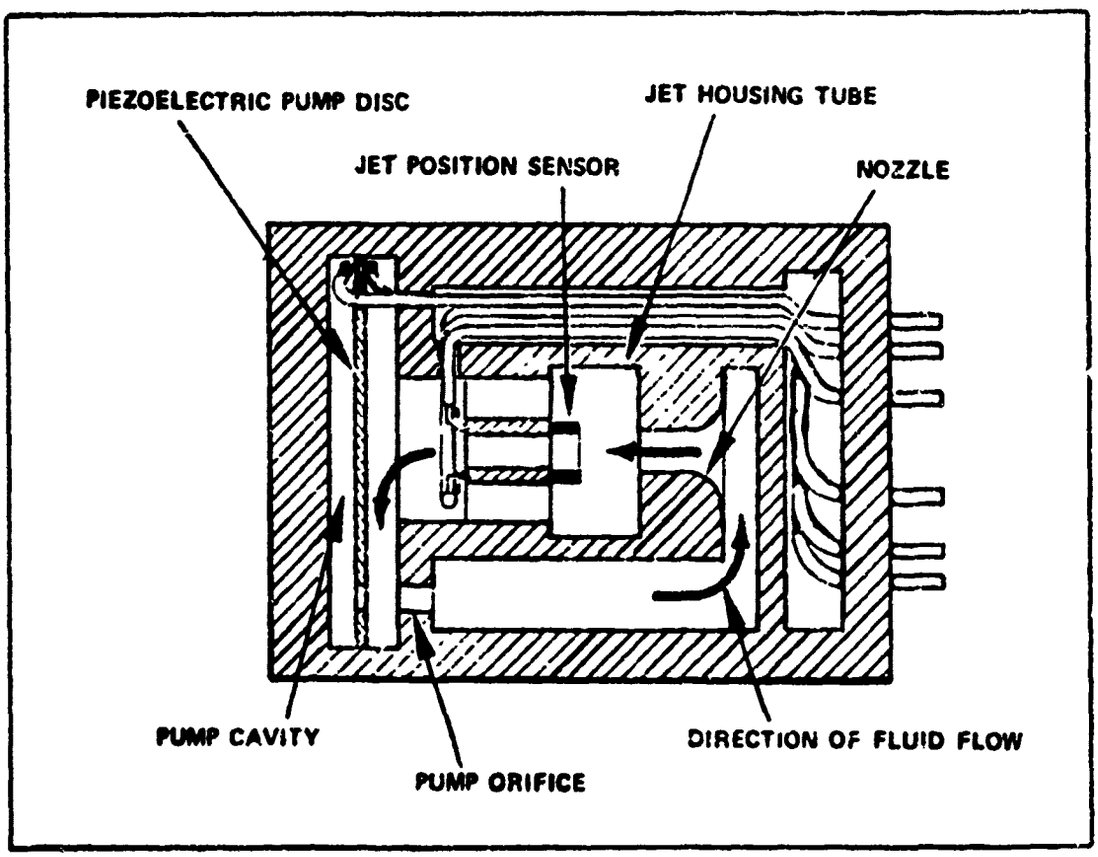


FIGURE 2.83 HYBRID RATE SENSOR

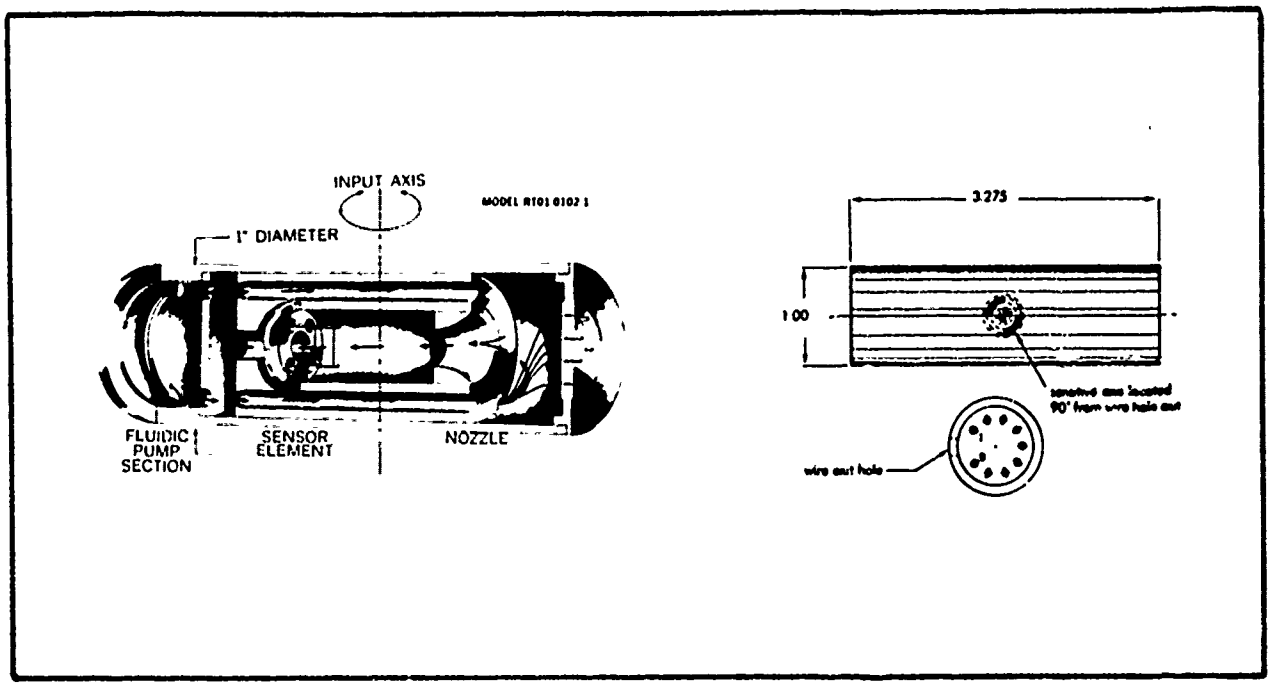


FIGURE 2.84 LAMINAR JET ANGULAR RATE SENSOR-HUMPHREY INC.

GENERAL INFORMATION

TYPE OF SENSOR: Angular Rate MOVING PARTS: None

PRINCIPLE OF OPERATION: Laminar gas flow past two heated resistance wires

DATA SOURCE: Humphrey Inc. Brochure

PRIMARY FLUID: Air INTERFACE: Electronic

READOUT PROVIDED: No, voltmeter required

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65^{o} to $+ 185^{o}$F PRESSURE: Unlimited Altitude

POWER SUPPLY FILTRATION: None

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: 10000 G any axis NOISE: Some sensitivity

ACCELERATION: 50 G VIBRATION: U

REFERENCE: Internal null

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Humphrey Inc.
9212 Balboa Avenue
San Diego, Cal. 92123

(Note: a similar product is distributed by Hamilton Standard under the name of "Superjet.")

POINT OF CONTACT: Mr. H.H. Kries (714)565-6631)

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $935.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: See Below *

FREQUENCY RESPONSE: Size dependent TIME RESPONSE: U

SUPPLY: .07 watts DC @ 1 volt

OUTPUT: ± 4 millevolts nominal

IMPEDANCE: Output, 100 ohms

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: ± 1% FS

SENSING RANGE: Threshold < 0.1% FS, MAXIMUM: 100°/Sec.

HYSTERESIS: 0.1% GAIN: $\frac{E_o}{e_i} = \frac{R_3 K}{R_1+R_2}$ **

OUTPUT SIGNAL: Electronic DC ± 50 mv.

CROSS SENSITIVITY EFFECTS: 0.5% FS for FS cross axis input

S/N RATIO: 500:1 EXPECTED LIFE: 10,000 hrs +

MTBF: U MCBF: U MTTR: U

* TRANSFER FUNCTION:

$$\frac{E_o}{W_i} = - \frac{K}{\left(1+ \frac{2\zeta}{W_n} S+ \frac{S^2}{W_n^2} \right)}$$

** E_o = Output Voltage
W_i = Rate of Rotation
ζ = Damping Ratio
W_n = Resonant Rate
S = Laplacian
e_i = Input Voltage
R_1, R_2, R_3 = Resistance Values

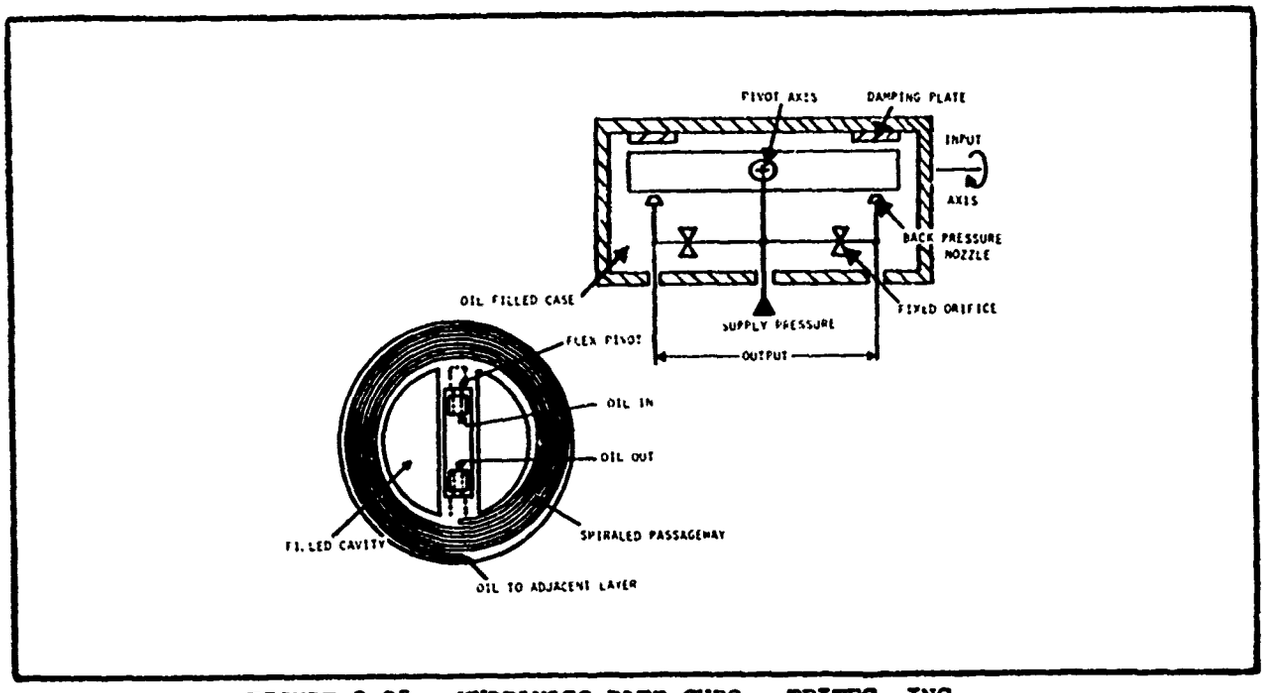


FIGURE 2.85 HYDRAULIC RATE GYRO - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Rate Gyro MOVING PARTS: Yes (Flexure Pivot)

PRINCIPLE OF OPERATION: Flow through helical chambers

DATA SOURCE: G.E. Contract No.'s DAAA09-74-C-2076, DAAA09-75-C-2038

PRIMARY FLUID: Hydraulic Oil INTERFACE: Oil-Electric

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Inertia of Hydraulic Oil

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- To 1600 psi

OUTPUT: PRESSURE- U

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: ± 470 deg/sec ACCURACY: ± 2%

SCALE FACTOR: 0.082 psi/deg/sec or 0.18 v/deg/sec

OUTPUT SIGNAL: Differential pressure or electrical readout

CROSS SENSITIVITY EFFECTS: U

NOISE: 0.1 deg/sec EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

2.4 Accelerometers

Accelerometers are basically defined as devices that yield an output signal as a function of the acceleration of the device itself. With the exception of one device currently in the development stage, nearly all accelerometers are fluidic and not flueric in nature. Fluidic accelerometers, which by definition eliminate the solid proof mass and use a purely fluid phenomenon, are still in the development stage. Difficulties have been encountered trying to derive a large output signal from the fluid. Thus, in the material presented for each of the following fluidic accelerometers, all described components have a minimum number of moving parts and use a substance of substantially different density to provide the accelerometer function. An example of a fluidic accelerometer is shown schematically in Figure 2.86.

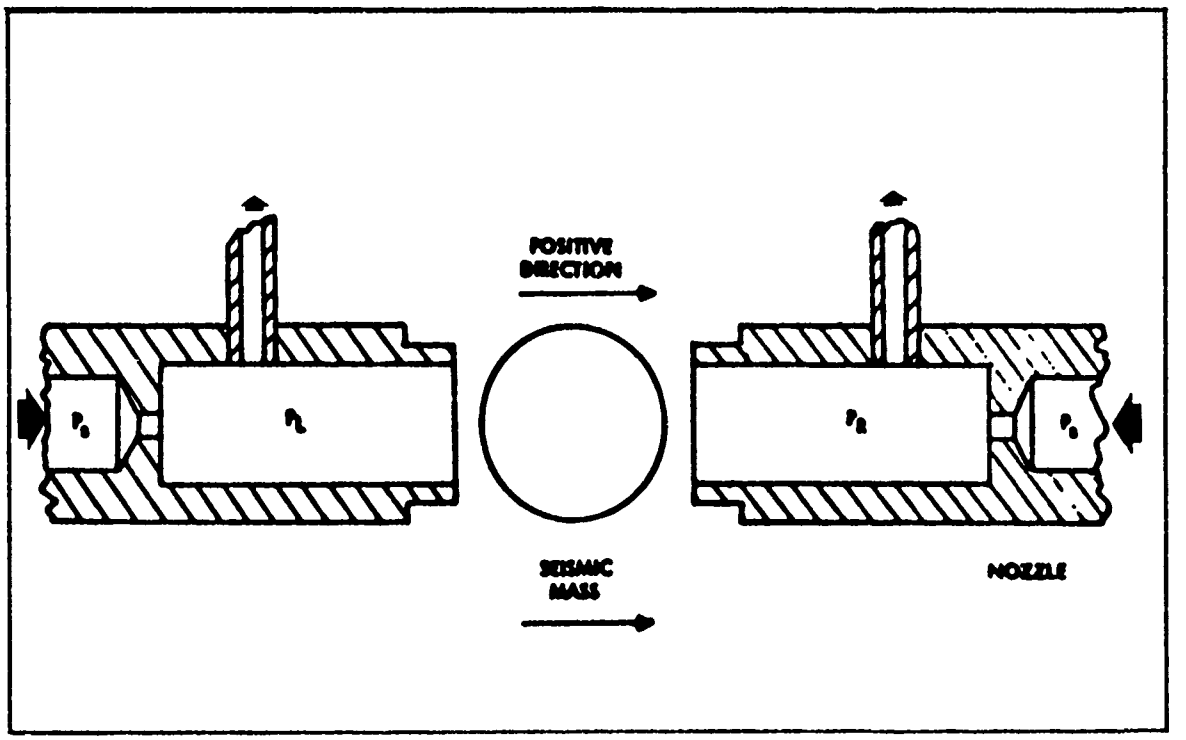


FIGURE 2.86 BASIC FLUIDIC ACCELEROMETER OPERATION

2.4.1 Seismic Mass Accelerometer

A seismic (proof) mass accelerometer in its simplest concept consists of the arrangement schematically depicted in Figure 2.87. Although there are several variations of this type of accelerometer, only an elementary concept is depicted. Basically, a continuous flow of gas enters the supply ports, and output flows and pressures are monitored. As the component is accelerated, the proof mass tends to remain stationary due to inertia. This relative movement causes a net change in the spacing between the proof mass and the walls of the casing, thus changing the resistance across the outputs and causing a pressure differential. The pressure differential balances the inertial force, and the output, $P_1 - P_2$, is nearly linear with regard to the acceleration. A constant scale factor is obtainable by manipulating the geometry and mass of the sensor. It should be also noted that to minimize the effect of static friction, the proof mass is usually supported by an air bearing. A variation of this concept is to support the proof mass by flexible cables, rather than an air bearing.

Typically, manufacturers have claimed fabrication of fluidic accelerometers having ranges of up to 400 G's with threshold frequencies in the order of 0.02 psid/G. They operate at supply pressures from 20 to 2200 psig, and output pressure levels, depending on the type of device, can range from 20 to 70% of the supply pressure. It should be noted also that all seismic mass accelerometers are analog devices.

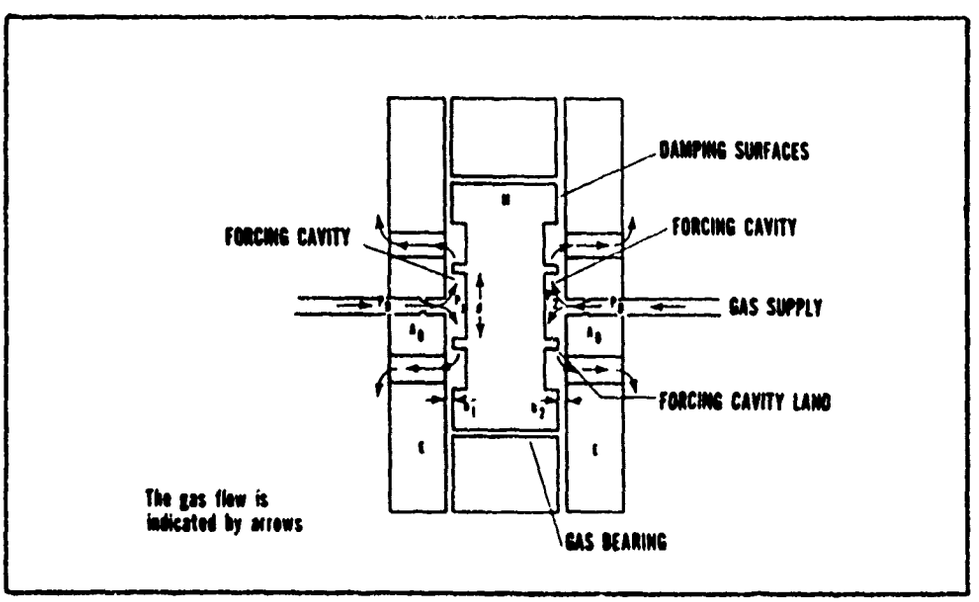


FIGURE 2.87 BASIC SEISMIC MASS ACCELEROMETER OPERATION

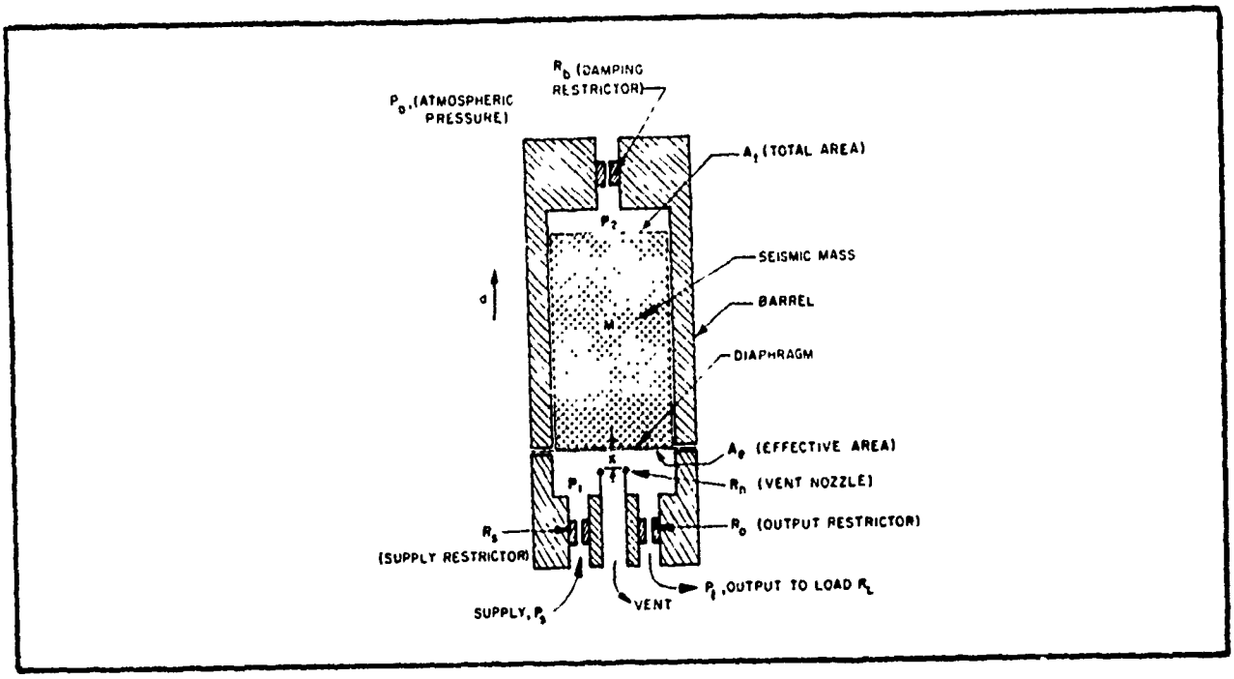


FIGURE 2.88 G SENSOR ACCELEROMETER

GENERAL INFORMATION

TYPE OF SENSOR: Acceleration

MOVING PARTS: Yes (Mass)

PRINCIPLE OF OPERATION: Seismic Mass Deflection of Diaphragm

DATA SOURCE: Fluidic State of the Art Symposium, 1974

PRIMARY FLUID: Air

INTERFACE: Air - Fluidic

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: 30 g's (Design Limit of Model)

VIBRATION: U

REFERENCE: Mass Inertia

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Franklin Institute Research Labs
Ben Franklin Parkway
Philadelphia, Pennsylvania 19103

POINT OF CONTACT: C.A. Belsterling (215) 448-1000

PRODUCT AVAILABILITY: Laboratory Model

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 280 Hz — TIME RESPONSE: 15 ms

SUPPLY: PRESSURE-Minimum: 0.5 Psig — Maximum: 20.0 Psig

FLOW-Minimum: 0.5 scfm — Maximum: U

POWER-Minimum: U — Maximum: U

OUTPUT: PRESSURE-Minimum: See Figure 2.89 — Maximum:

FLOW-Minimum: — Maximum:

POWER-Minimum: — Maximum:

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: Yes, Orifice can be changed for different sensitivity levels

LINEARITY: RANGE: See Figure — ACCURACY: U

THRESHOLD SENSING POINT: U — SENSITIVITY: U

HYSTERESIS: U — GAIN: U

OUTPUT SIGNAL: Analog Pressure

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U — EXPECTED LIFE: U

MTBF: U — MCBF: U — MTTR: U

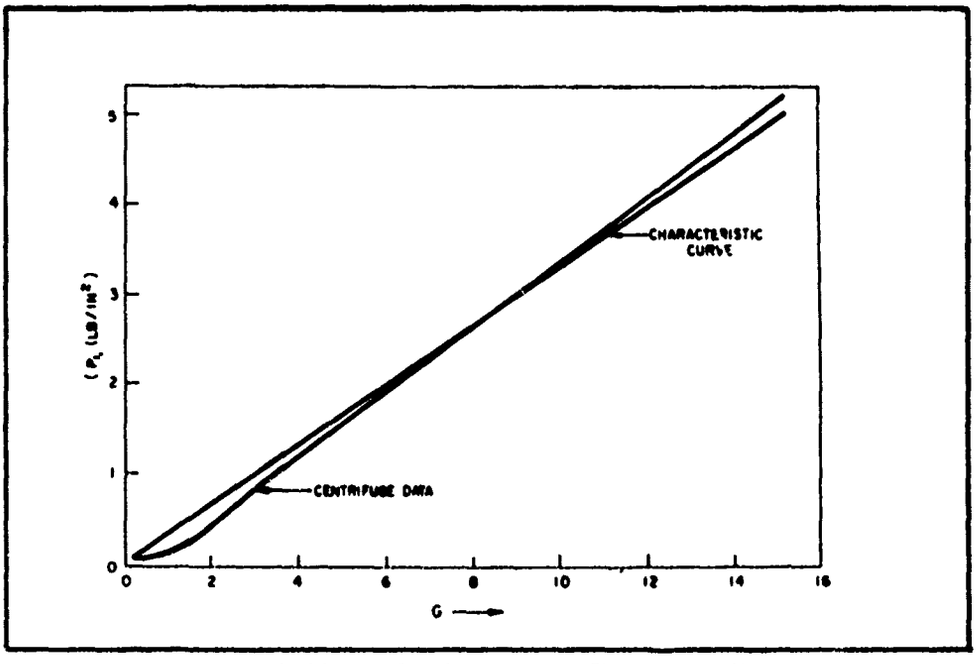


FIGURE 2.89 OUTPUT DATA FLUIDIC G SENSOR

2.4.2 Vibrating String Accelerometer

The vibrating string accelerometer employs a spring loaded proof mass which changes a feedback loop of a fluidic oscillator as a function of acceleration. A diagram of the basic concept is shown in Figure 2.90. Each accelerometer consists of the following components: a round wire, wire terminations, attenuation spring, the seismic mass, the input pressure nozzle, and the receiver nozzle.

The basic operation of this type of device is dependent on the phenomenon known as Strouhal or vortex shedding. Each nozzle impinges on a wire and the resultant vortex shedding creates an alternating pressure field which excites the wire in its natural mode of oscillation. Therefore, the nozzle flow is periodically interrupted by the wire motion, and a sinusoidal pressure pulse is detected by the receiver. These sinusoidal pulses are then fed into a beat frequency detector element, and the modulated pressure signal containing both the sum and difference frequencies are obtained. Experiments which have been conducted show that the Strouhal frequency (i.e., resonant frequency) of the wire is directly proportional to the square root of the tension in the wire itself. Further, as acceleration is applied along the input axis of the device, the tension of the wire effectively changes and, by measuring the beat frequencies, a signal is obtained that is directly proportional to the acceleration applied to the device. Note that the vibrating string system is basically a digital output accelerometer with signal proportional to the frequency shift.

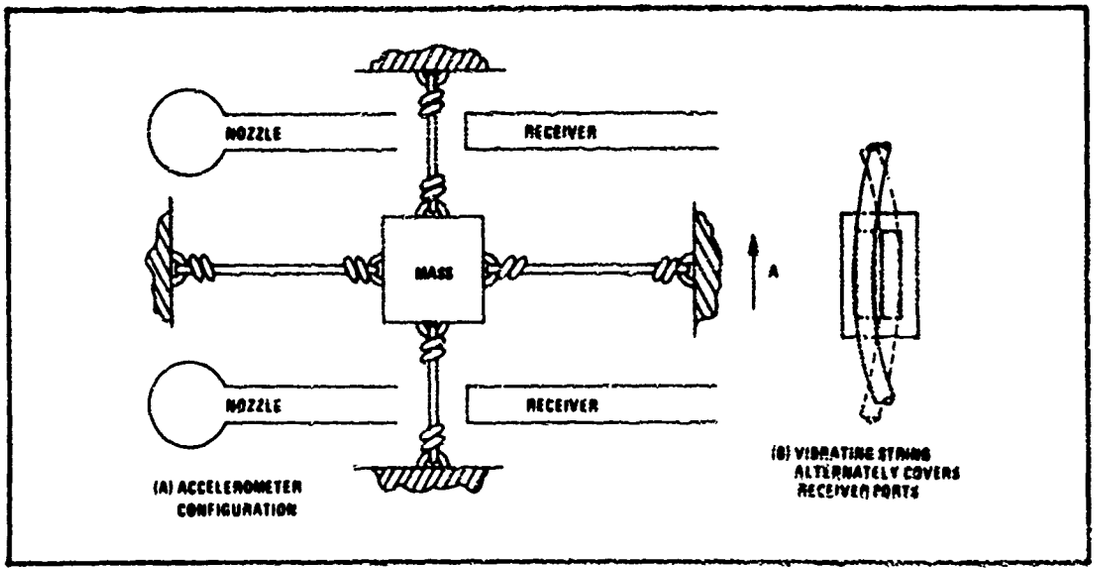


FIGURE 2.90 BASIC VIBRATING STRING ACCELEROMETER OPERATION

2.5 Temperature Sensors

One of the environmental parameters that can drastically alter the performance of any fluidic/flueric type of device is temperature. This has been used to advantage by many inventors and manufacturers to develop fluidic devices which sense temperature by monitoring both viscous and/or acoustic phenomena. Extensive testing and use of fluidic sensors in military aircraft have indicated that these devices have response characteristics of approximately 10 milliseconds.

Fluidic temperature sensors can be both analog or digital in nature. However, there are two basic methods by which the temperature of a fluid may be measured. The first technique (which usually yields the fastest response time) is to allow the fluid itself to pass through the measuring device. The second technique is to utilize the sensor as a probe inserted in the fluid medium. A typical schematic diagram is shown in Figure 2.91.

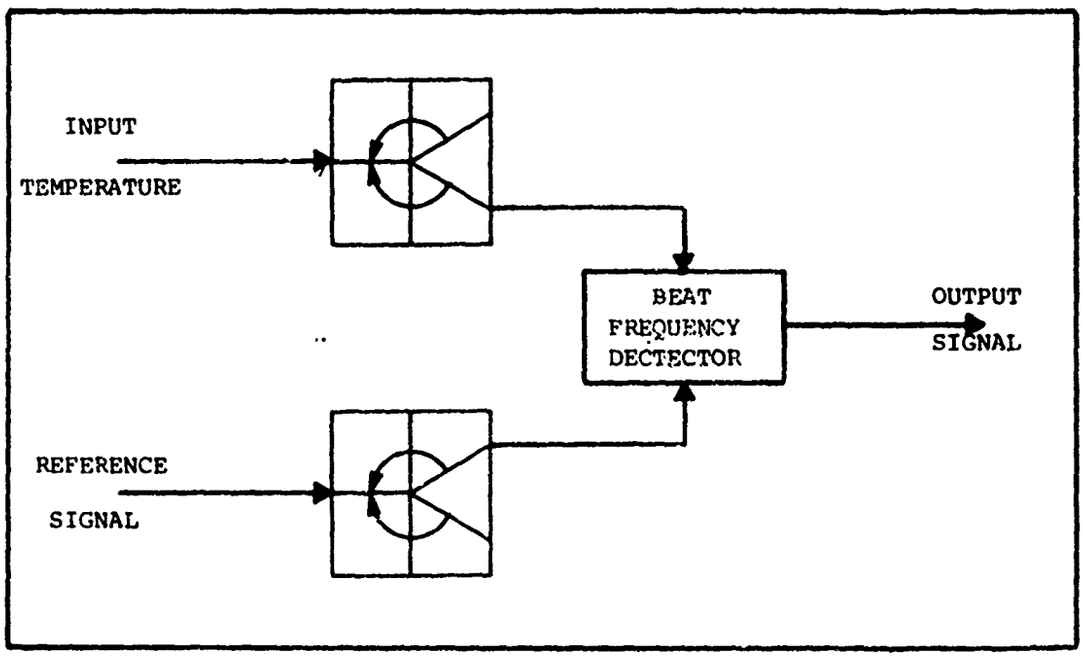


FIGURE 2.91 TYPICAL TEMPERATURE SENSOR DIAGRAM

2.5.1 Flow Resistance Sensor

Figure 2.92 depicts the generalized schematic diagram of a flow resistance type of temperature sensor. With this concept, the flow resistance is measured across the laminar section. It has been demonstrated that the pressure drop across this section is inversely proportional to the temperature. It should be noted, however, that this type of device effectively obeys this premise only in a specific operating regime. At an extremely low temperature, the pressure drop begins to increase with temperature. It should be noted also that this sensor is basically a high impedence unit, thus requiring signal amplification. Its net time response is a function of the total capacitance of the lines used to measure the pressure drop and the flow rate through the sensor itself.

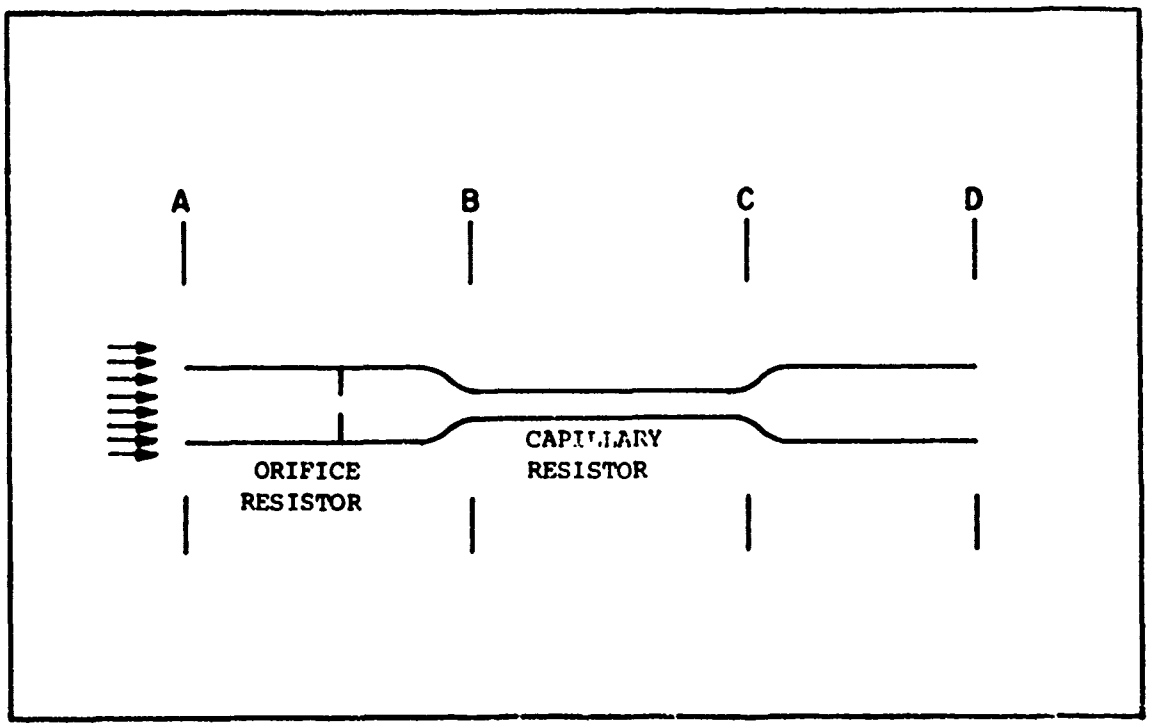


FIGURE 2.92 LAMINAR FLOW RESISTANCE TEMPERATURE SENSOR DIAGRAM

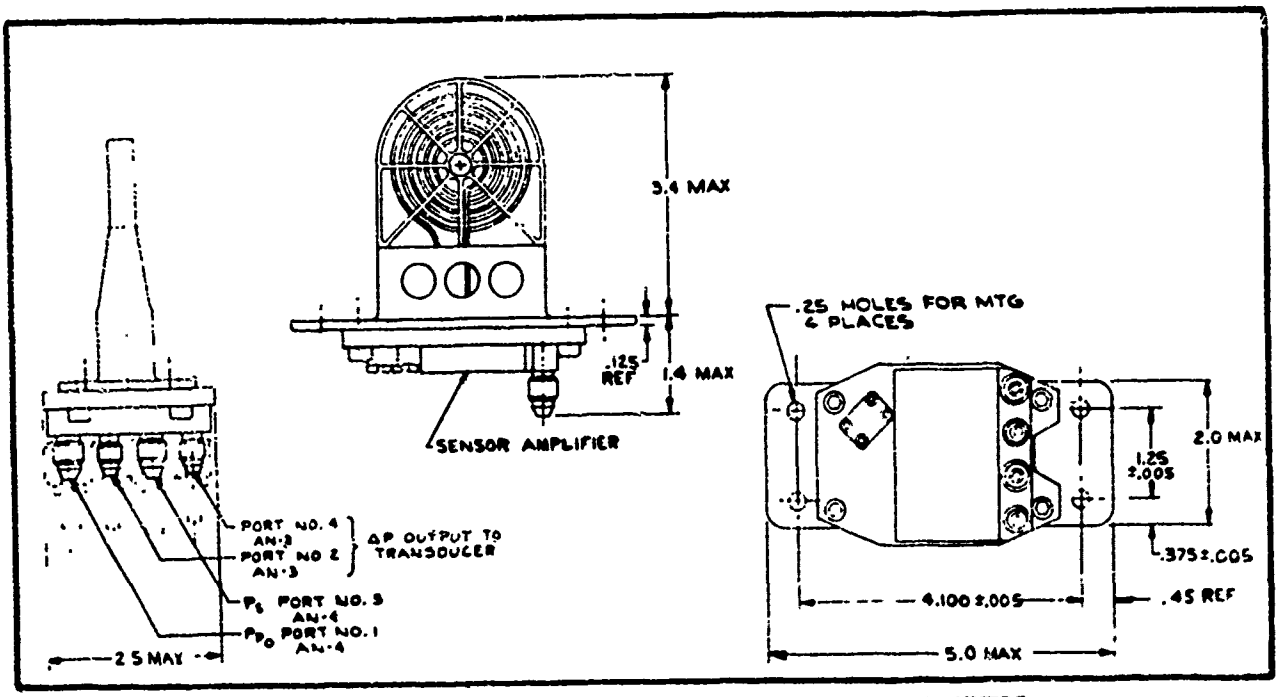


FIGURE 2.93 LAMINAR TEMPERATURE SENSOR - HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Laminar Temperature MOVING PARTS: None

PRINCIPLE OF OPERATION: Impedence change in capillary resistor.

DATA SOURCE: Honeywell Handbook: AM 263

PRIMARY FLUID: Air INTERFACE: None

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65° to 2000°F PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: Tested to 10,000 Hz

REFERENCE: Set pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell, Inc.
2600 Ridgway Parkway
Minneapolis, Minn. 55413

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: 1 second

SUPPLY: PRESSURE- As required

OUTPUT: PRESSURE- See below*

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.94

ACCURACY: 2.5%

SENSING RANGE: See Figure 2.94

HYSTERESIS: U

GAIN: $\frac{d\Delta P}{dt} = \frac{\Delta P}{\mu}\frac{d\mu}{dt}$ **

OUTPUT SIGNAL: Pressure

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: Unlimited

MTBF: U MCBF: U MTTR: U

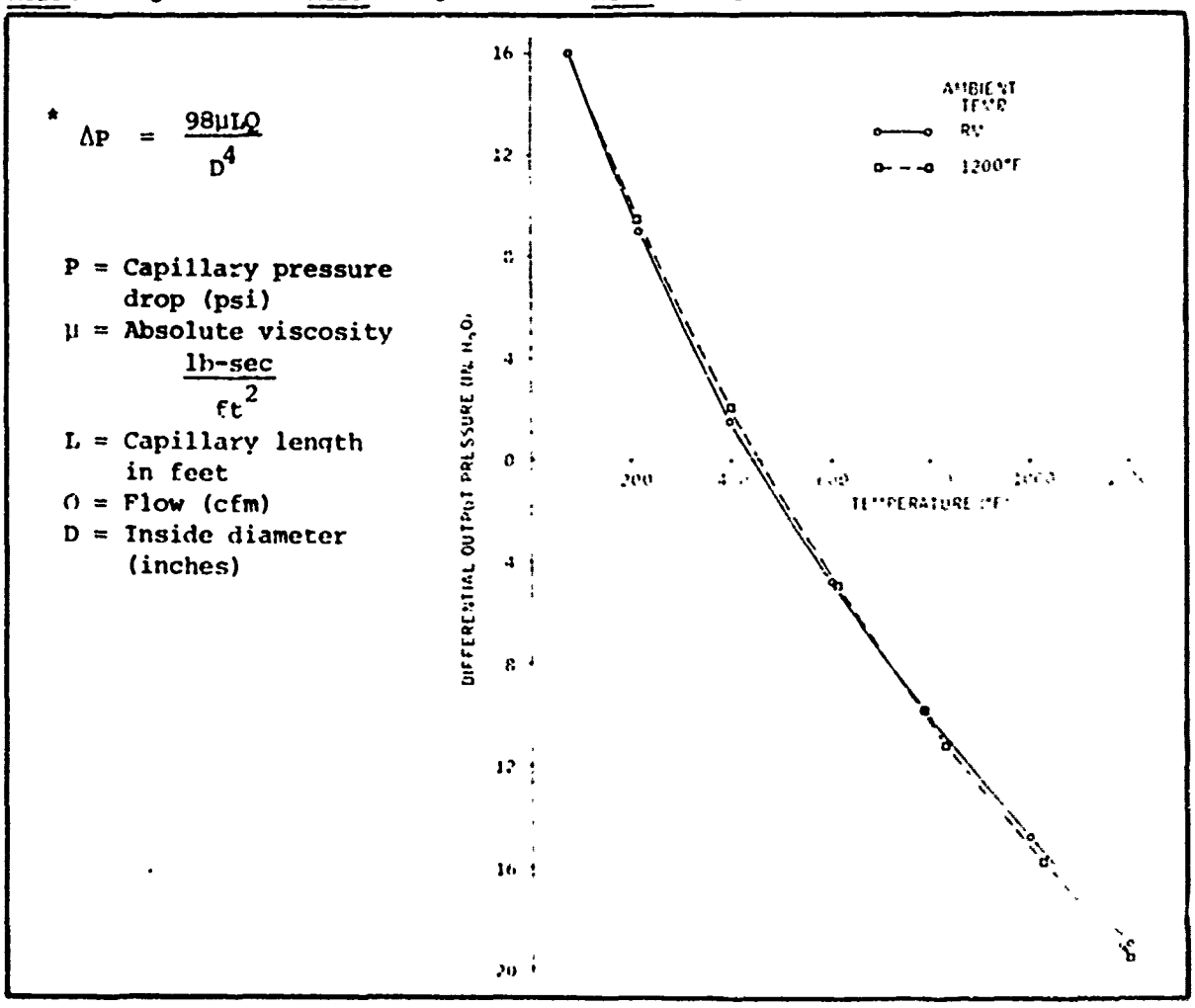


FIGURE 2.94 AVAILABLE DATA: LAMINAR TEMPERATURE SENSOR - HONEYWELL

2.5.2 Bridge Type Sensor

A modification of the basic flow resistance type of temperature sensor is known as the bridge type temperature sensor. Flow resistance elements are formed in a bridge network similar to that shown in Figure 2.95. They utilize the linear and non-linear characteristics of laminar and turbulent pressure drops in opposing bridge arms. Although some bridge type temperature sensors have been used by commercial manufacturers in specialized systems designed for specific applications, no commercial devices of this type are presently available as off-the-shelf units.

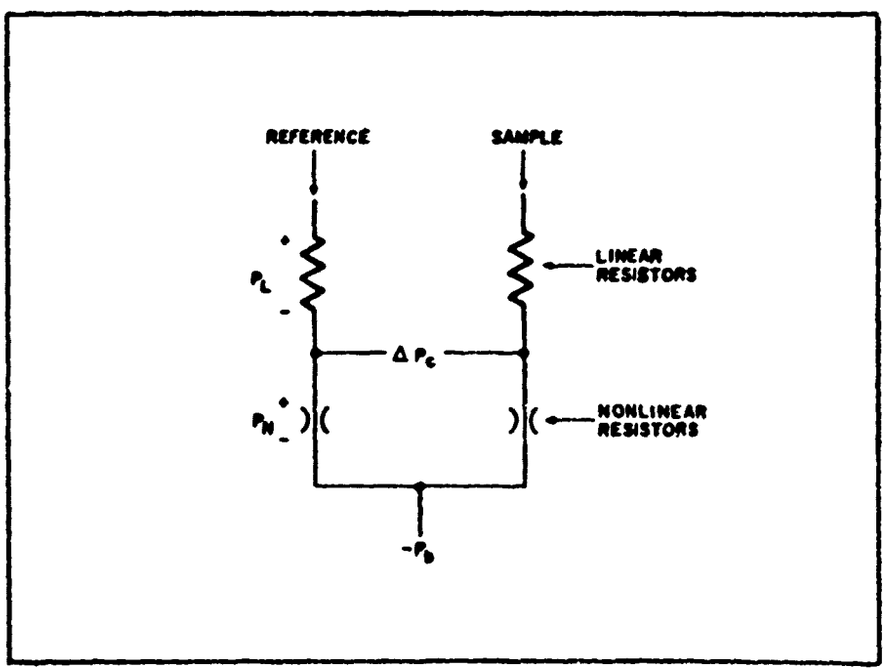


FIGURE 2.95 BRIDGE TYPE FLOW TEMPERATURE SENSOR DIAGRAM

2.5.3 Oscillator Type Sensor

The operation of an oscillator type of fluidic temperature sensor is based on the premise that the frequency of a fluid oscillator depends on the speed of wave propagation in the fluid medium. Since this wave propagation is a function of gas temperature, the frequency of oscillation, therefore, is a direct measure of the temperature differential or change. To provide an accurate reference and thus ensure that the oscillator frequency be independent of pressure, the sensor must be operated under essentially "choked" conditions. The basic bistable fluid oscillator is shown in Figure 2.96. Its method of operation is as follows. As the jet exits out of port A, some flow is returned through the feedback loop C, causing the jet to switch to the opposite side. The jet, now exiting out of side B, returns a portion of the fluid through the right feedback loop, thus causing the jet to again switch back, completing the cycle.

It can be shown that the period of oscillation of a fluidic temperature sensor is directly proportional to the length of one loop of the feedback and inversely proportional to the jet velocity and speed of wave propagation. Tests have shown that to increase the sensitivity of the device it is necessary to increase the frequency (i.e., reduce the feedback loop) at which the oscillator is operating. The shortest possible feedback loop for an oscillating type of sensor consists of an internal resonance chamber (or cavity) rather than the external ducts. With this type of arrangement, however, edgetone frequencies about the splitter are generated, and these are also effected by the temperature of the fluid. Response times for this device are claimed in the order of 0.01 second.

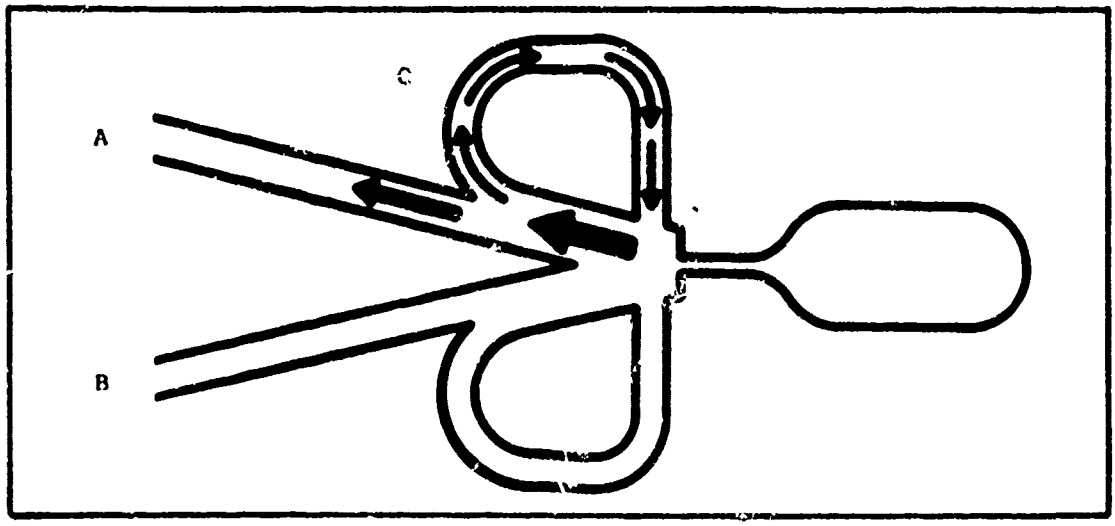


FIGURE 2.96 BASIC OSCILLATOR TEMPERATURE SENSOR

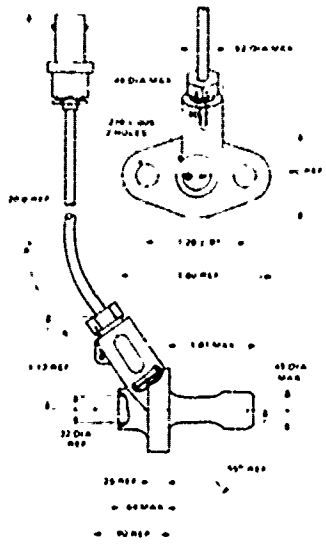


FIGURE 2.97 OSCILLATOR TEMPERATURE SENSOR - HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Turbine Inlet Temperature MOVING PARTS: No

PRINCIPLE OF OPERATION: Fluidic Oscillator

DATA SOURCE: Honeywell Brochure: ADC-346

PRIMARY FLUID: Air INTERFACE: Piezoelectric crystal

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: to 2000° F PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Oscillator frequency

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell, Inc.
2600 Ridgway Parkway
Minneapolis, Minn. 55413

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Off-the-shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $\frac{K_1}{(1 + \tau_1 S)} + \frac{K_2}{(1 + \tau_2 S)} = \frac{.74}{1 + 0.03S} + \frac{0.26}{1 + 6.7S}$

FREQUENCY RESPONSE: NA* TIME RESPONSE: 0.05 seconds

SUPPLY: 0.0008 to 0.0045 lbm/sec @ 5 to 85 psid

OUTPUT: See (*) below.

IMPEDANCE: U

SCALING ABILITY: No

LINEARITY: RANGE: 100° to 2000° F ACCURACY: ± 1.5 %

SENSING RANGE:

HYSTERESIS: None GAIN: NA

OUTPUT SIGNAL: Pneumatic converted to electric via piezoelectric crystal.

CROSS SENSITIVITY EFFECTS: Pressure dependent below 4 psid.

S/N RATIO: U EXPECTED LIFE: 2500 hrs @ 1800° F

MTBF: U MCBF: U MTTR: U

*Note: Output Frequency $\simeq K(T)^{1/2}$,

where K = Calibration Constant

T = Absolute Temperature

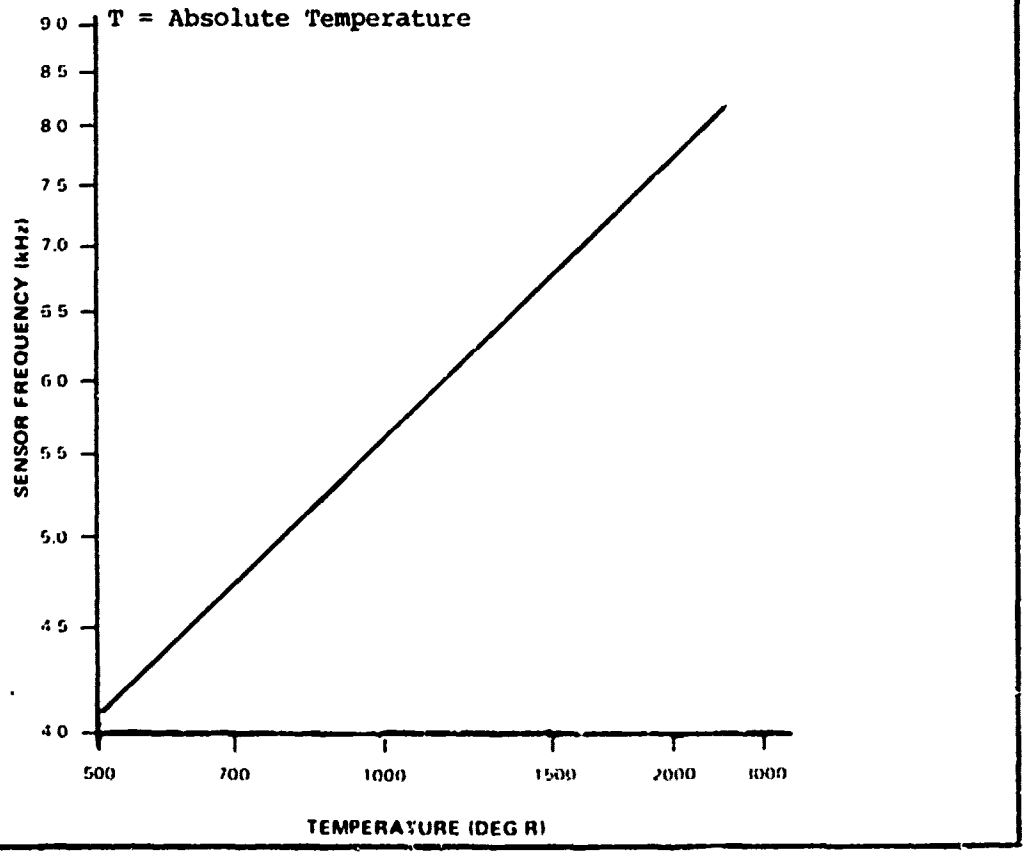


FIGURE 2.98 AVAILABLE DATA: OSCILLATOR TEMPERATURE SENSOR - HONEYWELL

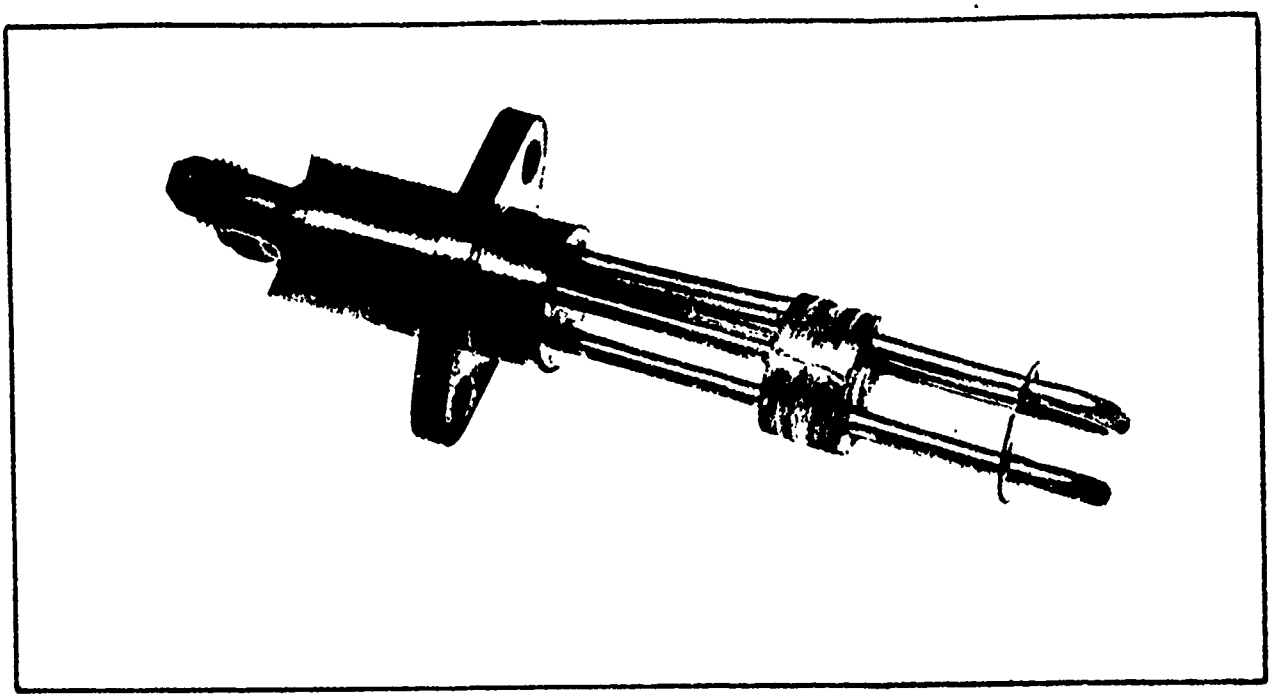


FIGURE 2.99 FEEDBACK OSCILLATOR TEMPERATURE SENSOR-AIRESEARCH

GENERAL INFORMATION

TYPE OF SENSOR: Temperature MOVING PARTS: None

PRINCIPLE OF OPERATION: Feedback oscillator, speed of sound dependent

DATA SOURCE: Airesearch Mfg. Co.

PRIMARY FLUID: Air INTERFACE: Piezo-Ceramic

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65°F to 1200°F (pneu.) PRESSURE: Not altitude limited

POWER SUPPLY FILTRATION: 20 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Oscillator Frequency, fluid density

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Airesearch Manufacturing Co. of Arizona
402 S 36th Street, P.O. Box 5217
Phoenix, Arizona 85010

POINT OF CONTACT: Mr. Frank Halpin (602) 267-4053

PRODUCT AVAILABILITY: Available on special order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $\frac{K}{1 + \tau s}$

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 3 psig FLOW: 0.05 lb/min

OUTPUT: PRESSURE- ± 1.0 psig

IMPEDANCE: U

SCALING ABILITY: N/A

LINEARITY: RANGE: non-linear function ACCURACY: ± 10° at FS

TEMPERATURE SENSING RANGE: -65°F to 1950°F

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Oscillating pressure

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: 5000 hrs

MTBF: U MCBF: U MTTR: U

2.6 Concentration Sensors

As defined here, concentration sensors are those devices that are used to monitor the percentage "mixture" of a gas. These devices are configured in one of three basic designs: the resistance bridge, the vortex, and the oscillator. Tests have shown that all have relatively low threshold sensitivity to a contaminant gas, but require amplification of their outputs to provide a useful signal.

2.6.1 Resistance Bridge Concentration Sensor

The resistance bridge concentration sensor is by far the simplest. Basically, it consists of both linear (viscosity dependent) and nonlinear (density dependent) resistors connected in a bridge circuit similar to that shown in Figure 2.100. The resultant differential pressure signal is proportional to the unknown concentration of the "used" gas. Experiments have shown that this type of device is quite sensitive to small concentrations (in the order of 100 parts per million) and the device has an output that is extremely linear. A basic variation of the resistance bridge type of circuit is the replacement of one of the resistors with one or more vortex type resistors. Since the resistance of the vortex resistor is due to angular momentum rather than viscosity effects, it is less affected by temperature changes. Consequently, a large differential pressure output depending upon temperature will be delivered by the amplifier.

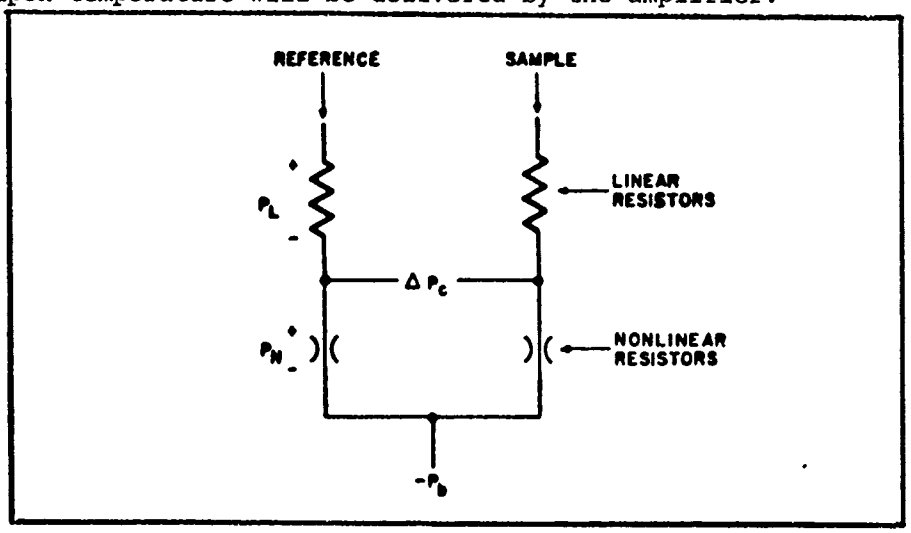
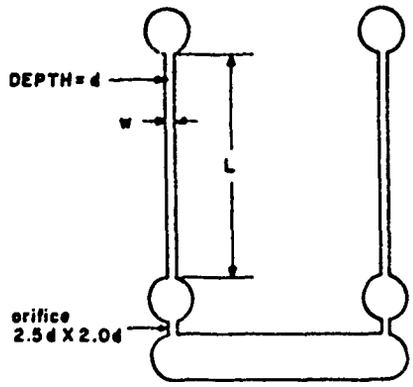


FIGURE 2.100 RESISTANCE BRIDGE CONCENTRATION SENSOR SCHEMATIC



b. SENSOR GEOMETRY (w=12.5d, L= 250d, d=0.01016 cm=0.004 in.)

FIGURE 2.101 BRIDGE TYPE CONCENTRATION SENSOR-HDL

GENERAL INFORMATION

TYPE OF SENSOR: Concentration MOVING PARTS: None

PRINCIPLE OF OPERATION: Linear and non linear resistance bridge

DATA SOURCE: Harry Diamond Laboratories

PRIMARY FLUID: Any gas INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Gas to be measured

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Harry Diamond Laboratory
2800 Powder Mill Road
Adelphi, Maryland 20783

POINT OF CONTACT: Mr. J. Joyce (301) 394-3080

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS *

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 0.03 sec/cm

SUPPLY: PRESSURE- 20 kPa

OUTPUT: PRESSURE- See Figure 2.102

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.102 ACCURACY: ± 2.5% of heading

SENSING RANGE: 0.1% to 100% Concentration in air

HYSTERESIS: U GAIN: Max. At.: P_L/P_b = .586

OUTPUT SIGNAL: 0.6 kPa/% CO_2

CROSS SENSITIVITY EFFECTS: Requires Temperature Compensation

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

NOTE* Data are for laboratory model only, used to measure CO_2 concentration in air. Concentration of other data will yield other results.

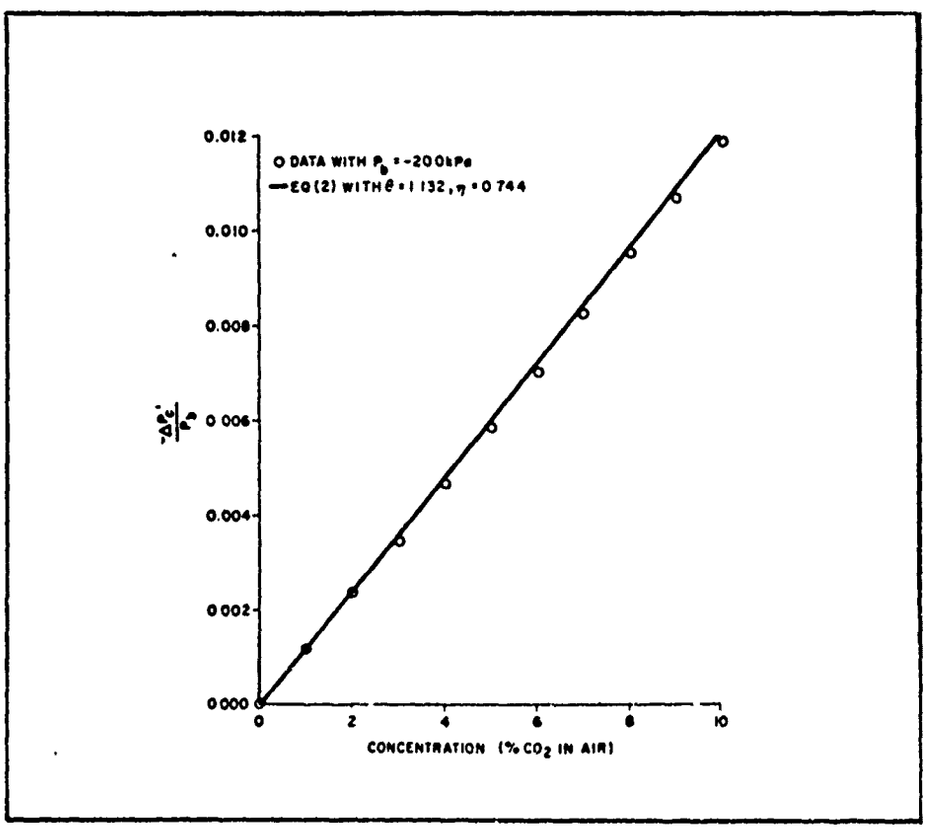


FIGURE 2.102 AVAILABLE DATA-CONCENTRATION SENSOR-HDL

2.6.2 Vortex Type Concentration Sensor

The vortex type concentration sensor operates on the principle of comparing a pressure differential of two fluid samples. One sample, which is a reference, is allowed to pass directly through a vortex chamber. The other sample is passed over a "scrubber" or catalyst bed to remove the desired gaseous element. The intensity of the vortex is a linear function of the density difference of the two samples. An angle of attack sensor provides the output signals.

Investigations have shown that practical designs have an expected time delay between 0.1 and 15 seconds and that linearity is achieveable over select ranges that are dictated by the sizing of the unit. A schematic diagram is shown in Figure 2.103.

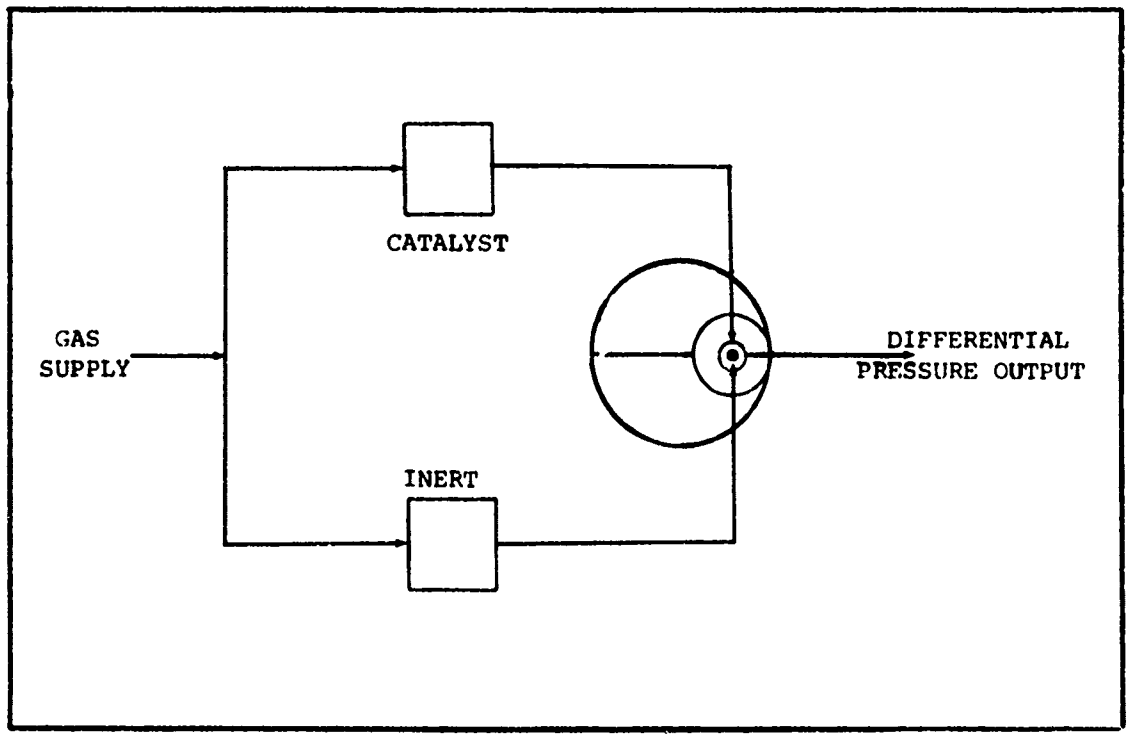


FIGURE 2.103 VORTEX TYPE CONCENTRATION SENSOR DIAGRAM

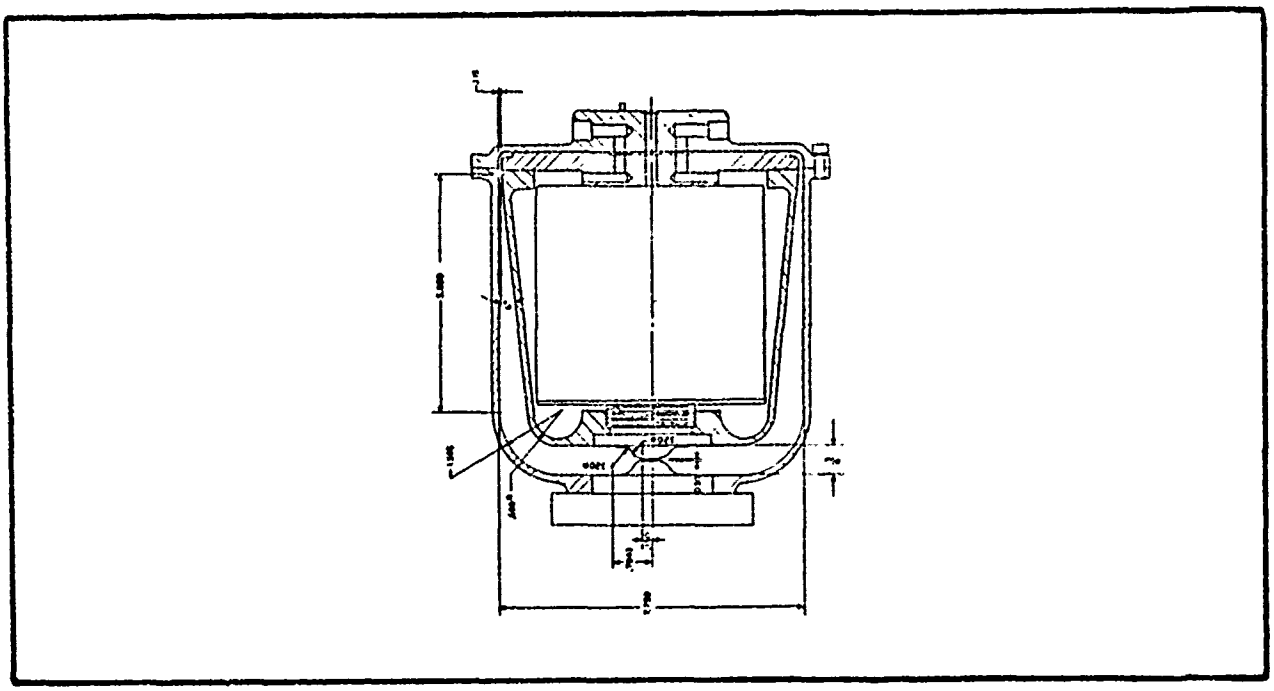


FIGURE 2.104 VORTEX CONCENTRATION SENSOR-NEOS Inc.

GENERAL INFORMATION

TYPE OF SENSOR: Concentration MOVING PARTS: None

PRINCIPLE OF OPERATION: Vortex Chamber

DATA SOURCE: NEOS Inc.

PRIMARY FLUID: Air INTERFACE: Air-Air

READOUT PROVIDED: No, Requires Barocel Pressure Transducer

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Gravitational Effect on Vortex

ORDERING INFORMATION

MANUFACTURER OR SOURCE: NEOS Inc.
3130 "O" Street
Lincoln, Nebraska 68510

POINT OF CONTACT: Mr. Arthur J. Ostdiek (402) 474-1660

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: 10 cps* TIME RESPONSE: U

SUPPLY: PRESSURE-Minimum: U Maximum: U

FLOW-Minimum: U Maximum: 1 liter/min.

POWER-Minimum: U Maximum: U

OUTPUT: PRESSURE-Minimum: Maximum:

FLOW-Minimum: Maximum:

POWER-Minimum: Maximum:

CONTROL: PRESSURE-Minimum:

IMPEDANCE: NA

SCALING ABILITY: U

LINEARITY: RANGE: U ACCURACY: U

CONCENTRATION SENSING RANGE: Dependent upon gas to be sensed

HYSTERESIS: Non Detected GAIN: See Figure

OUTPUT SIGNAL: Electronic (volts)

CROSS SENSITIVITY EFFECTS:

S/N RATIO: U EXPECTED LIFE:

MTBF: U MCBF: U MTTR: U

* Laboratory Model

2.6.3 Oscillator Concentration Sensor

The same basic type of device employed for oscillator temperature sensing is also employed for an oscillator concentration sensor. Claims are that the edgetone oscillator has a higher gain and better signal to noise ratio than that obtained from feedback loop type bistable element oscillators. The basic configuration is shown in Figure 2.105. For proper operation, the sensor relies upon a catalyst or "scrubber" to effectively change the density of the fluid being analyzed and thus provides a differential beat frequency. Tests have shown that the output is extremely linear over a 0 to 10 percent concentration range. At this time, no commercial devices of this nature are available.

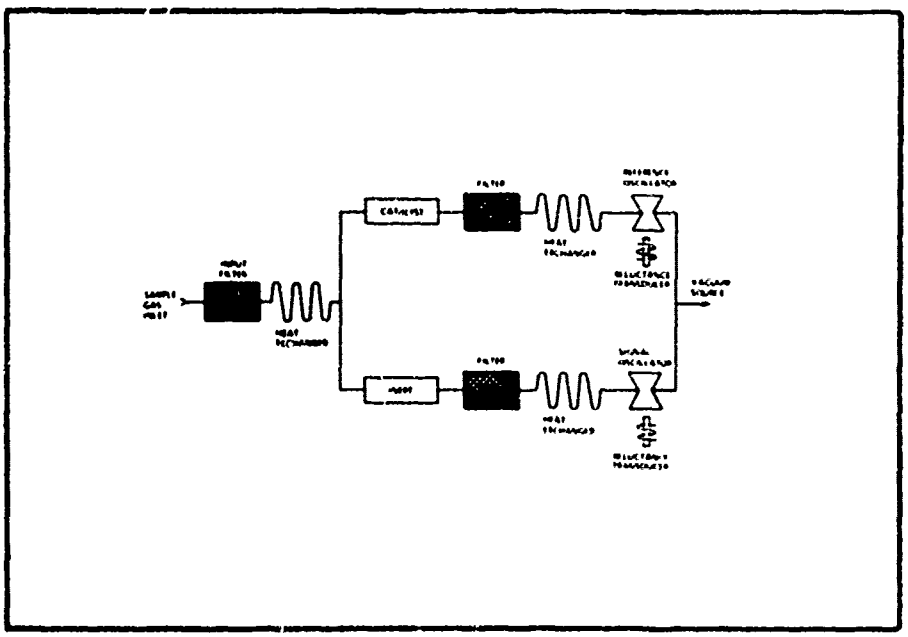


FIGURE 2.105 OSCILLATOR CONCENTRATION SENSOR

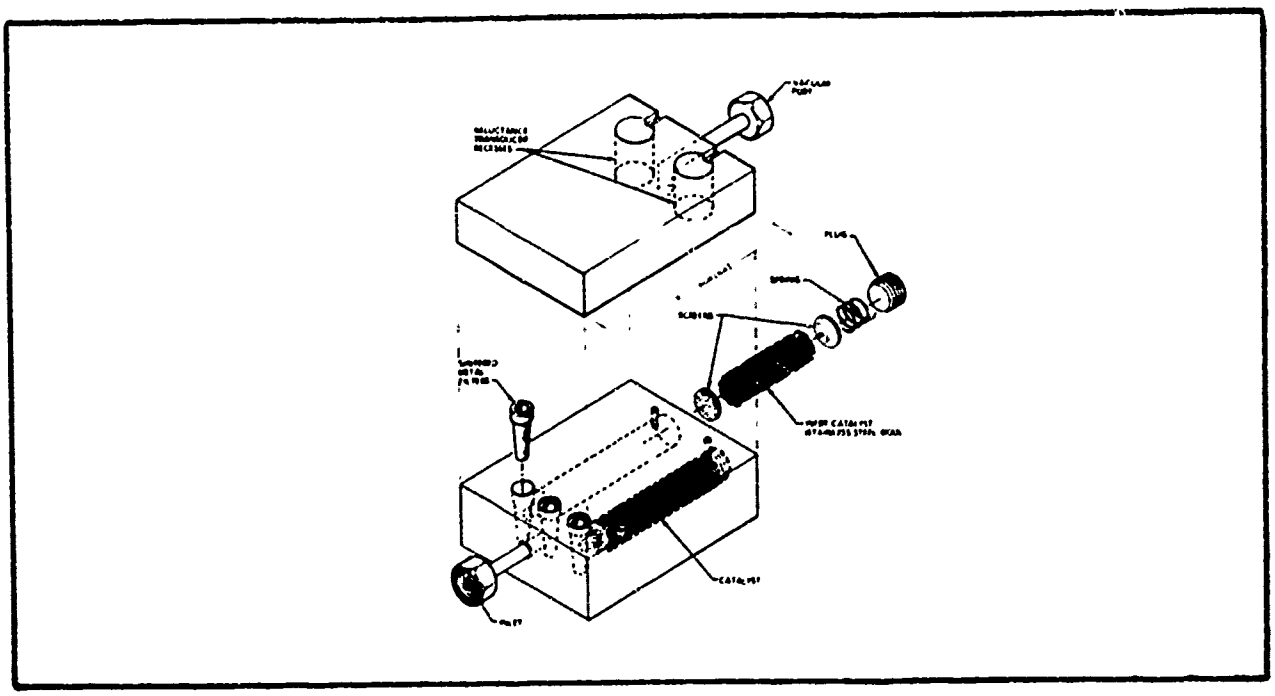


FIGURE 2.106 HYDROGEN CONCENTRATION SENSOR-MCDONNELL

GENERAL INFORMATION

TYPE OF SENSOR: Concentration

MOVING PARTS: None

PRINCIPLE OF OPERATION: Oscillation device for hydrogen detection. Sonic oscillation is a function of gas constant.

DATA SOURCE: NASA, Kennedy Space Ctr. Mr. W.K. Helms

PRIMARY FLUID: Gas

INTERFACE: U

READOUT PROVIDED: U

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 0^{o} to 150^{o}F

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: U

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: U

REFERENCE: Ambient pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: McDonnell Douglas Astronautic Co.
P.O. Box 600
Titusville, Florida 32780

POINT OF CONTACT: Mr. G.W. Ree (305) 269-4100

PRODUCT AVAILABILITY: Laboratory Device

COST: $1500.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: 1 v. D.C. per 0% Hz

FREQUENCY RESPONSE: 0.3 Hz TIME RESPONSE: 2.5 sec.

SUPPLY: NOMINAL: 17" Hg vacuum

OUTPUT: PRESSURE- U

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: 0 to 5% ACCURACY: 0.5% FS

CONCENTRATION SENSING RANGE: Threshold, 500 PPM

HYSTERESIS: NA GAIN: NA

OUTPUT SIGNAL: DC null, oscillating pressure

CROSS SENSITIVITY EFFECTS: Insensitive to Helium background

S/N RATIO: U EXPECTED LIFE: 10 years

MTBF: U MCBF: U MTTR: U

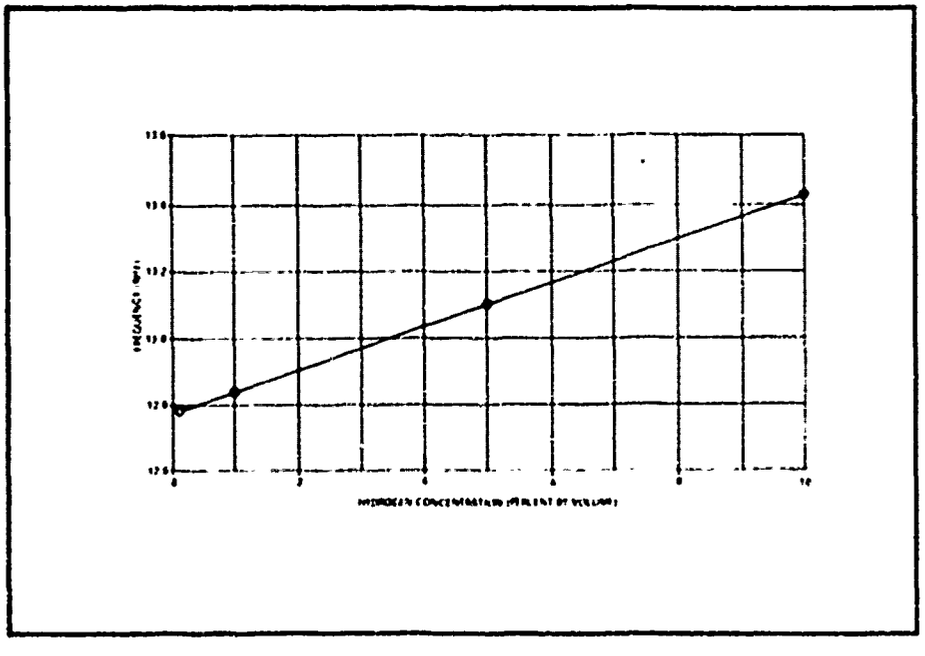


FIGURE 2.107 AVAILABLE DATA-HYDROGEN CONCENTRATION SENSOR-MCDONNELL

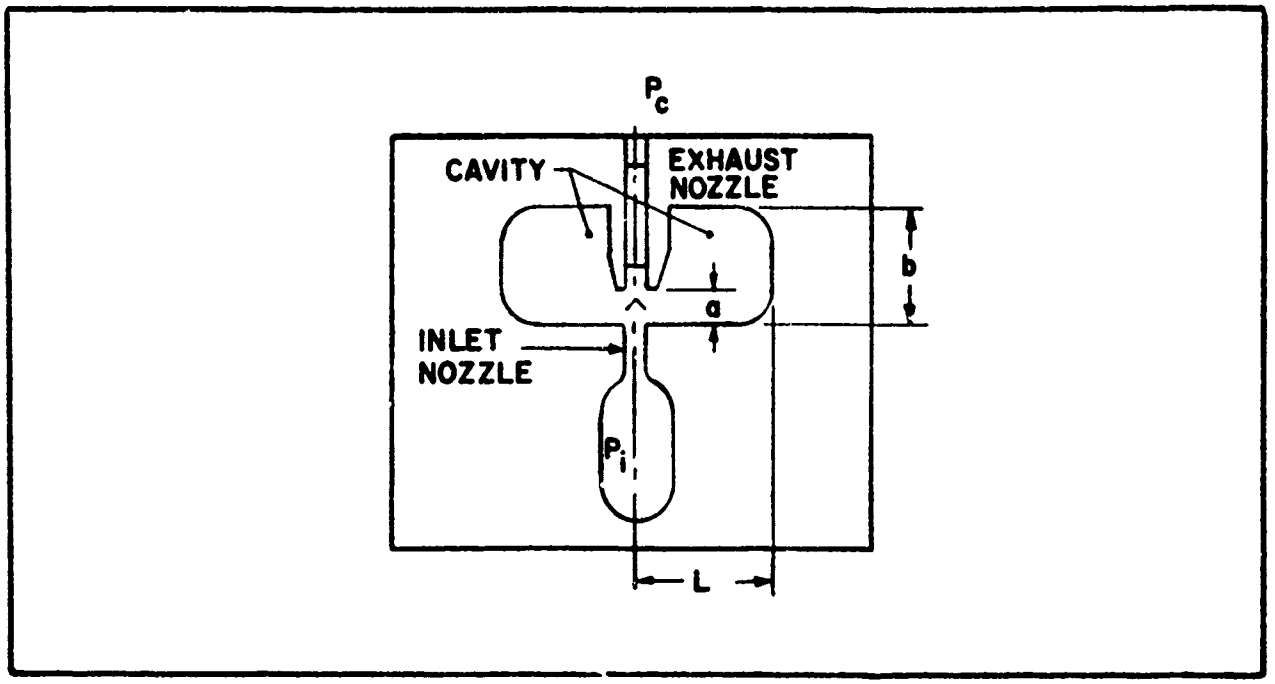


FIGURE 2.108 EDGETONE OSCILLATOR CONCENTRATION SENSOR-HDL

GENERAL INFORMATION

TYPE OF SENSOR: Concentration MOVING PARTS: None

PRINCIPLE OF OPERATION: Edgetone Frequency oscillator

DATA SOURCE: Harry Diamond Laboratory

PRIMARY FLUID: Air INTERFACE: Air-Fluidic

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 4000°F PRESSURE: U

POWER SUPPLY FILTRATION: Yes

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Oscillating edgetone frequency

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Harry Diamond Laboratories
2800 Powder Mill Road
Adelphi, Maryland

POINT OF CONTACT: Mr. James Joyce (301) 394-3080

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 0.01 sec

SUPPLY: PRESSURE- U

OUTPUT: PRESSURE- See Figure 2.109

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: 0.10% - 100% ACCURACY: U

CONCENTRATION SENSING RANGE: 0.10% - 100%

HYSTERESIS: U GAIN:

OUTPUT SIGNAL: Oscillating Pressure, frequency dependent on gas concentration

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

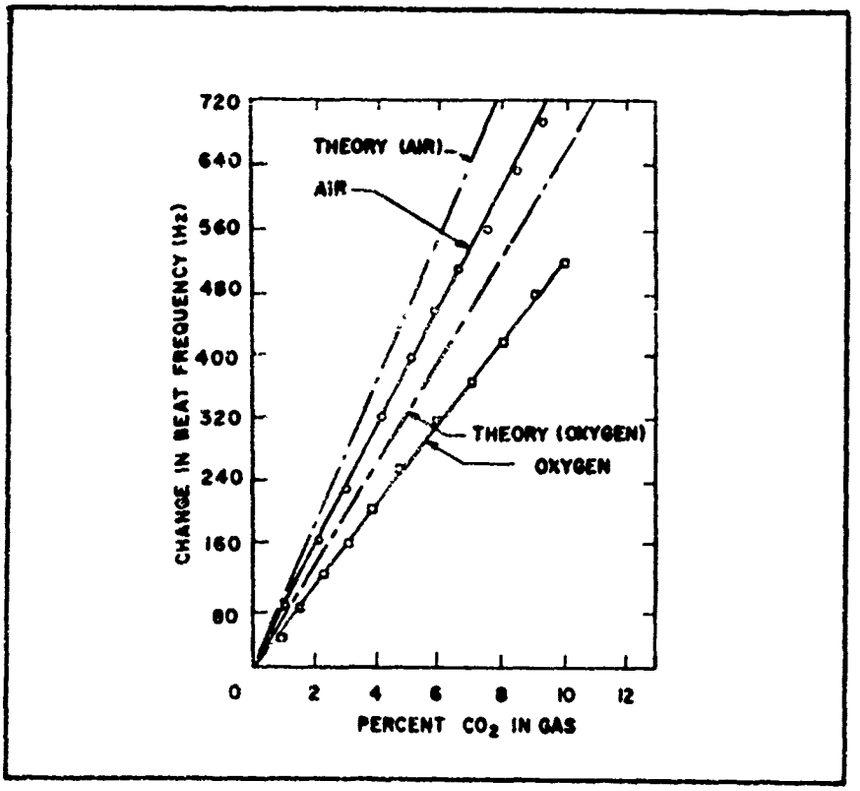


FIGURE 2.109 AVAILABLE DATA-EDGETONE OSCILLATOR CONCENTRATION SENSOR-HDL

2.7 Miscellaneous Sensors

In addition to the specific sensors previously discussed, a number of sensors have been developed for other applications. Typically, these devices fall into the general categories of densitometers, flow meters, pressure transducers, and attitude gyros. Many of these devices are more fluidic than fluieric in nature, because they contain one or more moving parts to supplement the sensing function.

2.7.1 Densitometers

The fluid densitometer is used for primary sensing of the desity measurement of fluids. As shown in the schematic diagram in Figure 2.110, its operation is based upon the interaction of free turbulent jets. Its principle of operation is as follows.

Basically, the unit is comprised of two chambers, a reference chamber and a measurement chamber. Identical turbulent jets issue from each of two nozzles into their respective chambers, and each jet impinges upon a receiver port. The reference chamber has only a small exit port and essentially becomes a capacitance when filled with the supply fluid. The measuring chamber is open to ambient pressure, and thus has an infinite capacitance. Since the pressure profile of the jet must change as a function of the density of the material, measurement of the pressure differential at the output demonstrates that the resulting signal is logarithmical and varies as a function of both the temperature and pressure of the fluid. Only one device of this type currently exists.

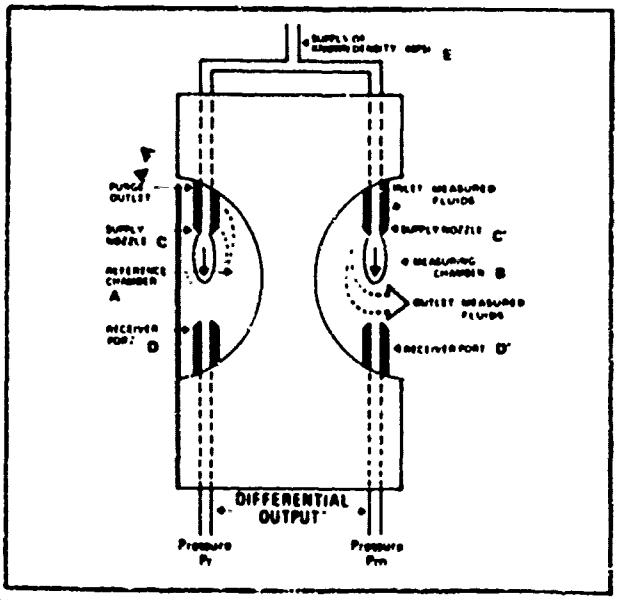


FIGURE 2.110 BASIC DENSITOMETER DIAGRAM

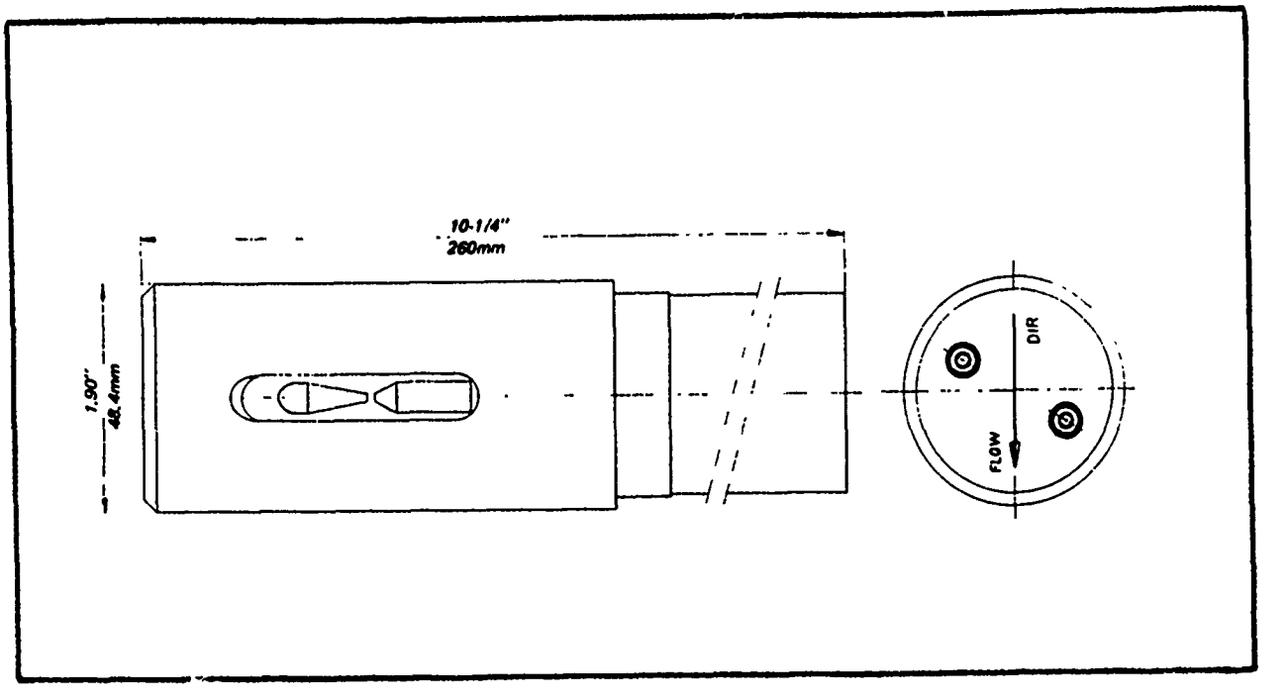


FIGURE 2.111 DENSITOMETER-FLUIDYNAMIC DEVICES LTD.

GENERAL INFORMATION

TYPE OF SENSOR: Densitometer MOVING PARTS: None

PRINCIPLE OF OPERATION: Difference in dynamic pressures of turbulent jets on receiver ports

DATA SOURCE: FluiDynamic Devices Ltd.

PRIMARY FLUID: Gas, liquid INTERFACE: Gas-Gas, Liquid-Liquid

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -200°F to 1200°F PRESSURE: 300 psig

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: Slight contamination with reference fluid of known density

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Jet stagnation pressure

ORDERING INFORMATION

MANUFACTURER OR SOURCE: FluiDynamic Devices Limited
3216 Lenworth Drive
Mississauga, Ontario
Canada L4X2G1

POINT OF CONTACT: P.W. Gooch (416) 625-9501

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE:	U		TIME RESPONSE:	10 ms
SUPPLY: PRESSURE-Minimum:	40 psig		Maximum:	80 psig
FLOW-Minimum:	1 scfm		Maximum:	2 scfm
POWER-Minimum:	130 W		Maximum:	520 W
OUTPUT: PRESSURE-Minimum:	See Figure 2.112		Maximum:	See Figure 2.112
FLOW-Minimum:			Maximum:	
POWER-Minimum:			Maximum:	
CONTROL: PRESSURE-Minimum:	N/A			
IMPEDANCE:	N/A			
SCALING ABILITY:	Yes			
LINEARITY: RANGE:	See Figure 2.112		ACCURACY:	0.1% Sg
MEASUREMENT RANGE:	See Figure 2.112			
HYSTERESIS:	None		GAIN:	NA

OUTPUT SIGNAL: Digital pressure change

CROSS SENSITIVITY EFFECTS: U

S/N RATIO:	U			EXPECTED LIFE:	U
MTBF:	U	MCBF:	U	MTTR:	U

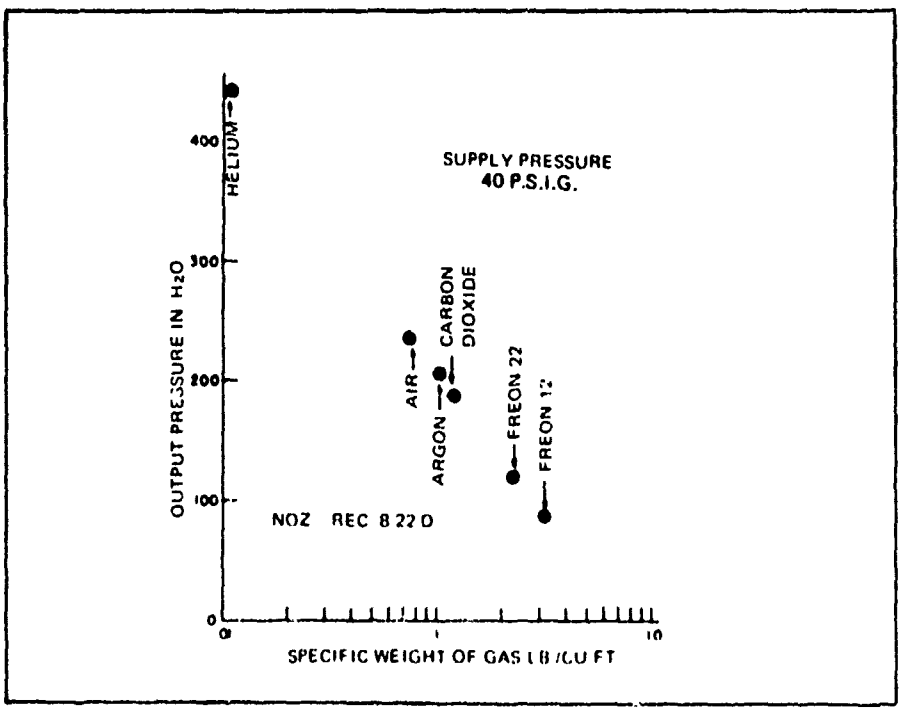


FIGURE 2.112 AVAILABLE DATA: DENSITOMETER - FLUIDYNAMIC DEVICES LTD.

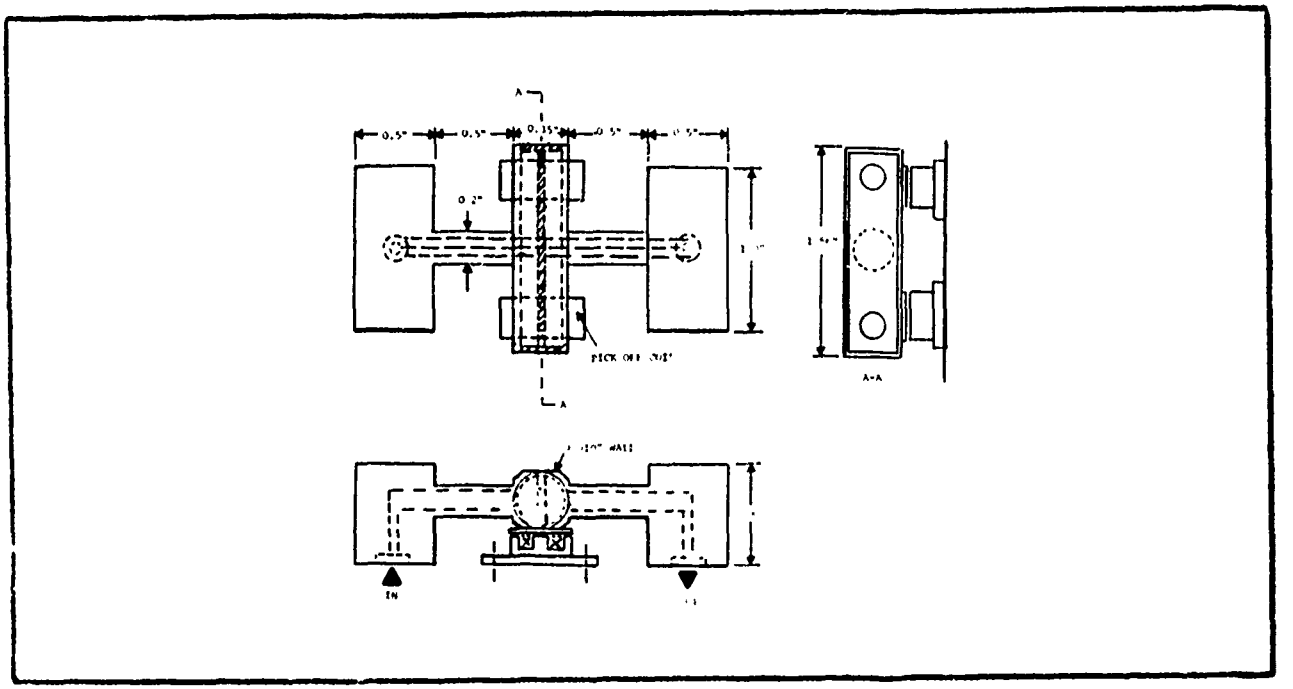


FIGURE 2.113 DENSITOMETER - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Densitometer MOVING PARTS: Yes (Flexure Cylinder)

PRINCIPLE OF OPERATION: Balanced torsional spring with f proportional to fluid density.

DATA SOURCE: G.E.Report "Fluidic Mass Fuel Flow Transmitter," Phase I (12/75)

PRIMARY FLUID: Oil, kerosene, jet fuel INTERFACE: Oil-Electronic

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: >100°C PRESSURE: 2,000 psi

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: None (Tested 3 axis)

REFERENCE: Tube resonance characteristics

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $f = \frac{1}{2\pi} \left(\frac{K_T}{[J_c + J_f(sg)]}\right)^{\frac{1}{2}*}$

FREQUENCY RESPONSE: U TIME RESPONSE: 1 sec

SUPPLY: PRESSURE- As required

OUTPUT: PRESSURE- 90% of supply

IMPEDANCE: NA

SCALING ABILITY: Yes

LINEARITY: RANGE: To limit of reading ACCURACY: ± 1.3%

SENSING RANGE: 0.86 to 1 sg**

HYSTERESIS: U GAIN: 0.00270 sg/Hz**

OUTPUT SIGNAL: Electronic pulsed frequency

CROSS SENSITIVITY EFFECTS: Slight temperature effect

S/N RATIO: NA EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

*f = Frequency
K_T = Spring Constant of Torsion Tube
J_c = Container Inertia
J_f = Fluid Inertia for sg = 1
**sg = Specific Gravity

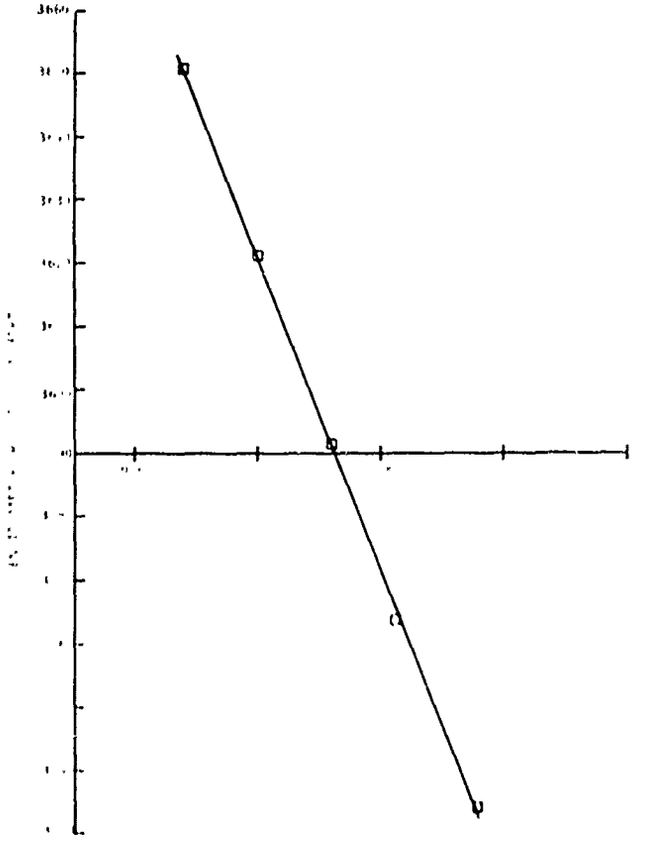


FIGURE 2.114 AVAILABLE DATA: DENSITOMETER - TRITEC, INC.

2.7.2 Attitude Gyros

There are two basic types of fluidic gyros currently designed and tested. Both are hybrids in that they employ some type of mechanical moving element to obtain satisfactory performance. The first, a two-axis pneumatic pick-off (TAPP), consists of a rotor supported on a gas bearing. This rotor is the only mechanical moving part of the entire gyroscope. The remaining components include a gas supply bottle, a Squibb igniter device, an internal regulator, a two-axis pneumatic pick-off, and a fluidic summing module. It is available in both analog and digital configurations. Claims are that this type of gyro can obtain satisfactory performance when subjected to over 1200 G's.

A slightly different type of attitude gyro employs the same basic principle, but includes a device for automatic sequencing for start-up and uncaging. This is shown in Figure 2.115. With this concept, the natural rotor boundary layer is used as a power source for the sensor. These types of devices are available only on special order from select manufacturers, and none are available as commercial off-the-shelf items.

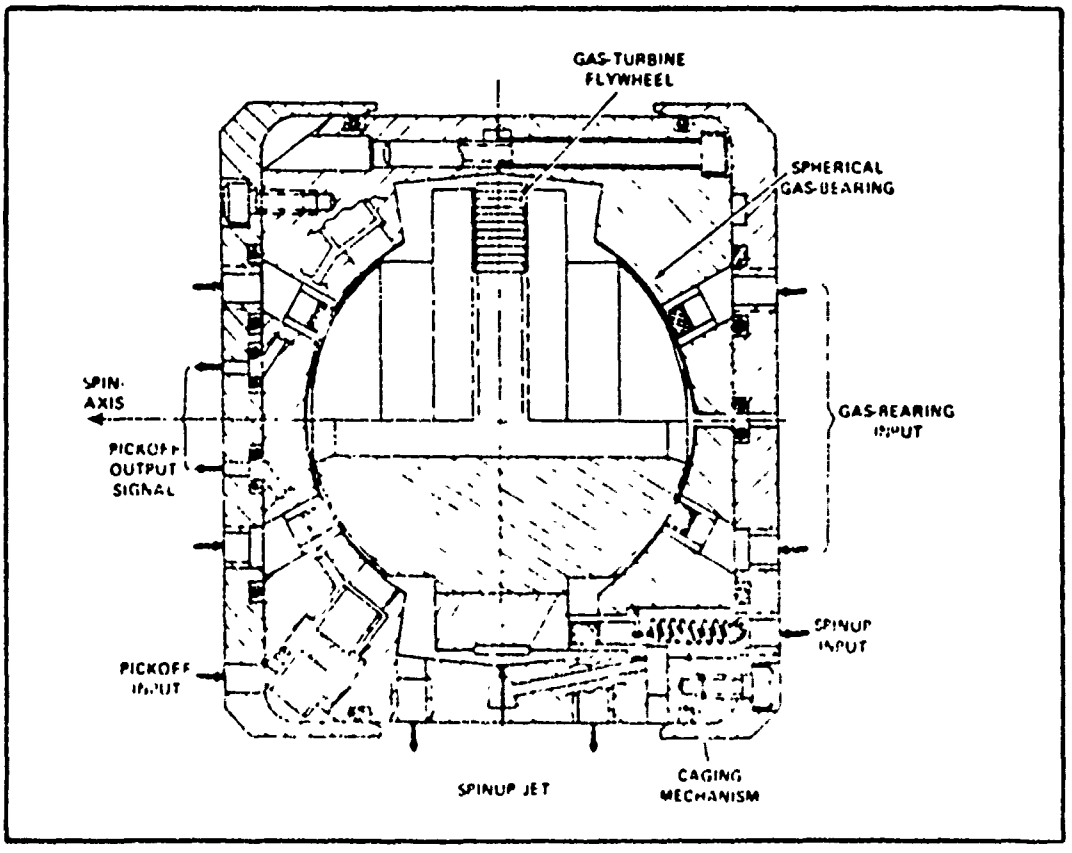


FIGURE 2.115 BASIC ATTITUDE GYRO SCHEMATIC

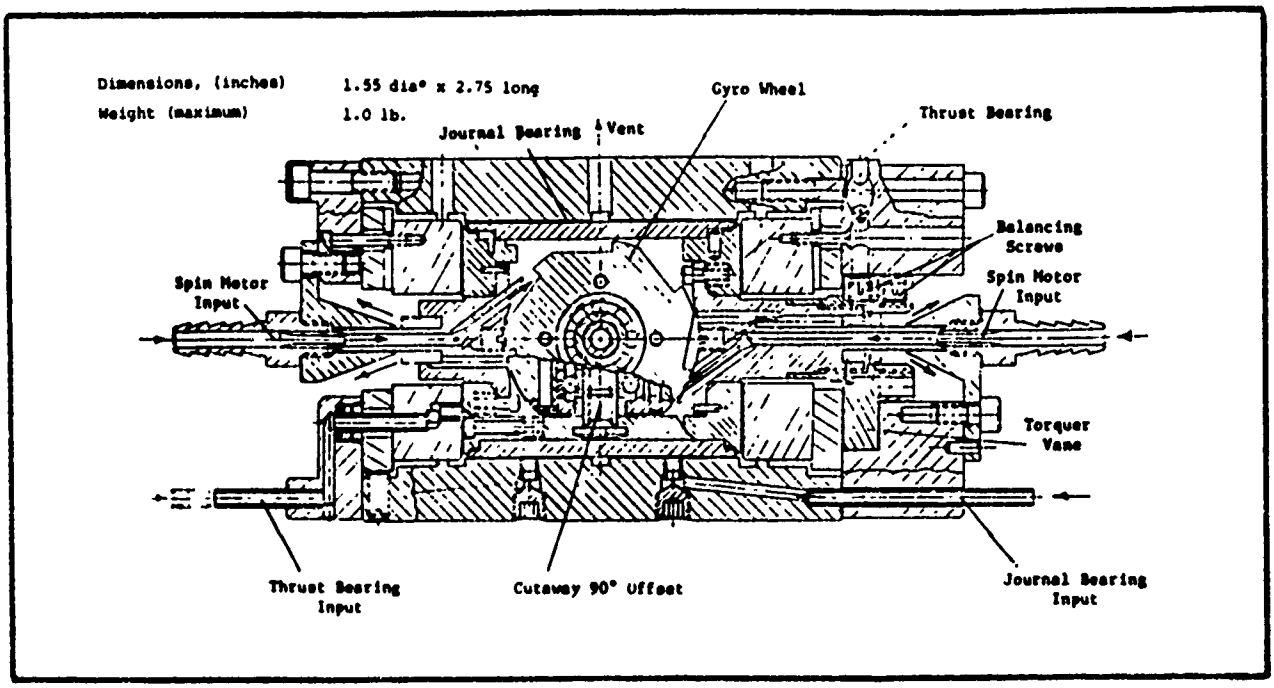


FIGURE 2.116 SINGLE DEGREE OF FREEDOM GYRO-MARTIN MARIETTA

GENERAL INFORMATION

TYPE OF SENSOR: Attitude Gyro (one axis) MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Pneumatically Spun mass on air bearings

DATA SOURCE: Naval Air Systems Command

PRIMARY FLUID: Air INTERFACE: Air-Fluidic

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65° to 165°F PRESSURE: U

POWER SUPPLY FILTRATION: Yes

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: 20 g's (any axis) VIBRATION: U

REFERENCE: Moment of Inertia of spinning mass

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Martin Marietta Corporation
Aerospace Division, Box 5837
Orlando, Florida 32805

POINT OF CONTACT: Mr. Rolf Broderson (305) 352-2000

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: 1 scfm @ 28 psid to Spin Drive

0.34 scfm @ 55 psig to each Thrust Bearing

0.175 scfm @ 265 psig to each Journal Bearing

OUTPUT: PRESSURE-Minimum: 0.06 psid/degree

FLOW-Minimum: U

POWER-Minimum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: $\pm 5^{\circ}$ ACCURACY: U

MINIMUM SENSING RATE: U

HYSTERESIS: U DRIFT RATE: $<1.0^{\circ}$/hr/g

OUTPUT SIGNAL: Pressure proportional to angular change

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

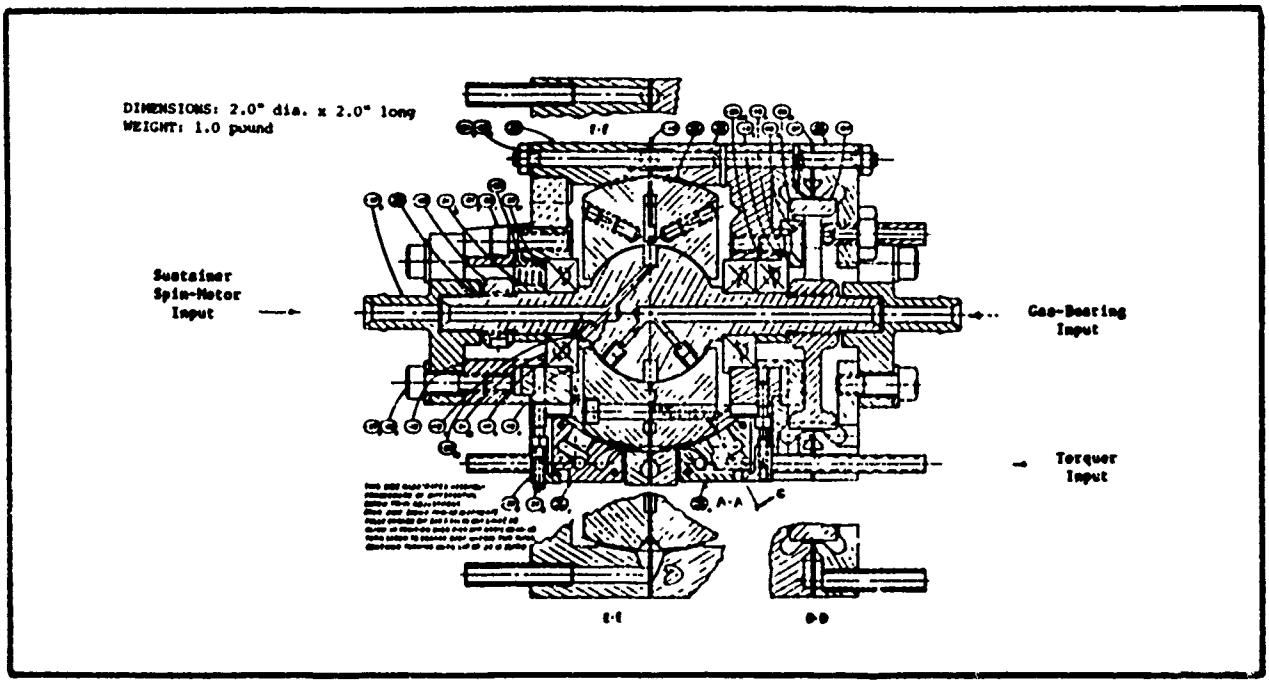


FIGURE 2.117 TWO-DEGREE OF FREEDOM GYRO-MARTIN MARIETTA

GENERAL INFORMATION

TYPE OF SENSOR: Attitude Gyro (two axis) MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Pneumatically Spun Mass on Air Bearings

DATA SOURCE: Naval Air Systems Command

PRIMARY FLUID: Air INTERFACE: Air-Fluidic

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65^{o} to 165^{o} F PRESSURE: U

POWER SUPPLY FILTRATION: Yes

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: 20 g's (any axis) VIBRATION: U

REFERENCE: Moment of Inertia of Spinning Mass

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Martin Marietta Corporation
Aerospace Division, Box 5837
Orlando, Florida 32805

POINT OF CONTACT: Mr. Rolf Broderson (305) 352-2000

PRODUCT AVAILABILITY: Laboratory Item

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: 1.0 scfm @ 15 psig to Spin Drive
1.5 scfm to Gas Bearings

OUTPUT: PRESSURE-Minimum: 0.06 psid/degree Maximum: U
FLOW-Minimum: U Maximum: U
POWER-Minimum: U Maximum: U

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: $\pm 5^{\circ}$ ACCURACY: U

HYSTERESIS: U DRIFT RATE: $< 3^{\circ}$/hr/g

OUTPUT SIGNAL: Pressure proportional to Angular Change

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

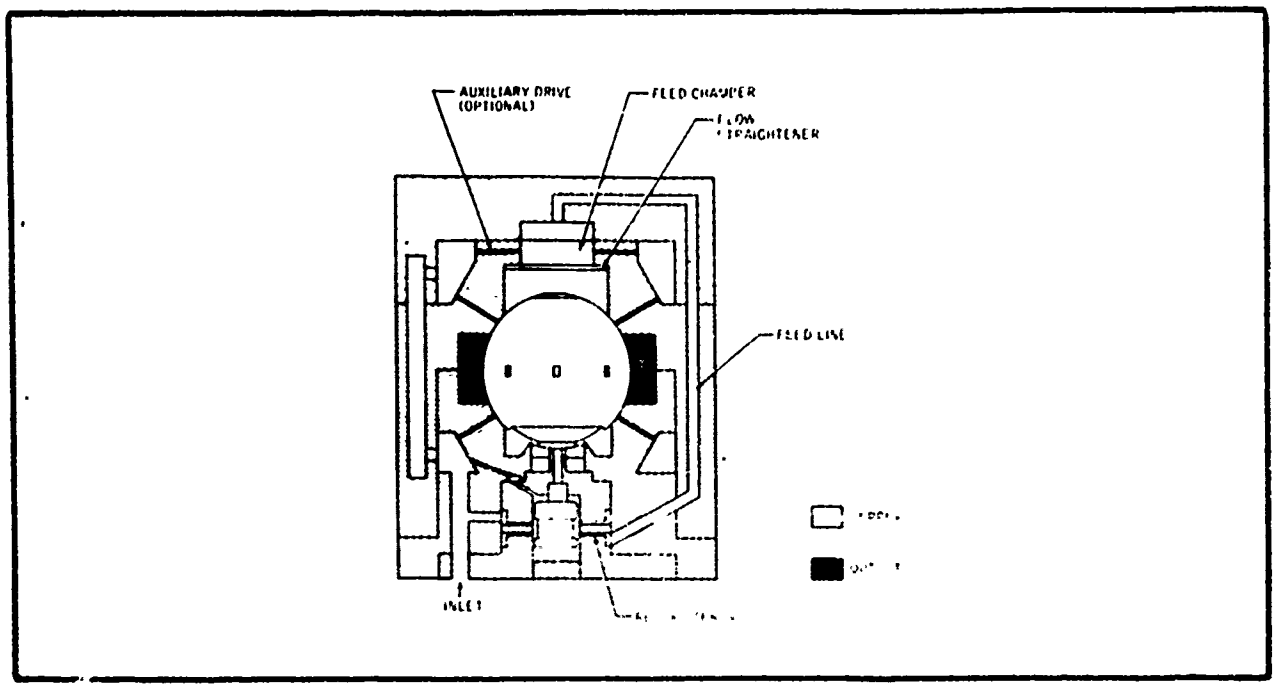


FIGURE 2.118 TWO AXIS GYRO - HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Two-axis Gyro MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Spinning Mass

DATA SOURCE: Honeywell

PRIMARY FLUID: Air INTERFACE: None

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -65°F to 165°F PRESSURE: U

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: Tested to 150 g's VIBRATION: U

REFERENCE: Inertial position

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell, Inc.
2600 Ridgway Parkway
Minneapolis, Minn. 55413

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Developed for special program

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 10 to 60 psi FLOW: 0.165 scfs

DRIVE: PRESSURE- 2 to 10 psi

IMPEDANCE: U

SCALING ABILITY: No

LINEARITY: RANGE: 0.025° - 10° ACCURACY: 1% FS

SENSING RANGE: ± 10°

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Pneumatic

CROSS SENSITIVITY EFFECTS:

S/N RATIO: 200 EXPECTED LIFE:

MTBF: U MCBF: U MTTR: U

SCALE FACTOR: 0.00282 psi/degree/psi support pressure

DRIFT: 6.4°/hr RESOLUTION: 0.025°

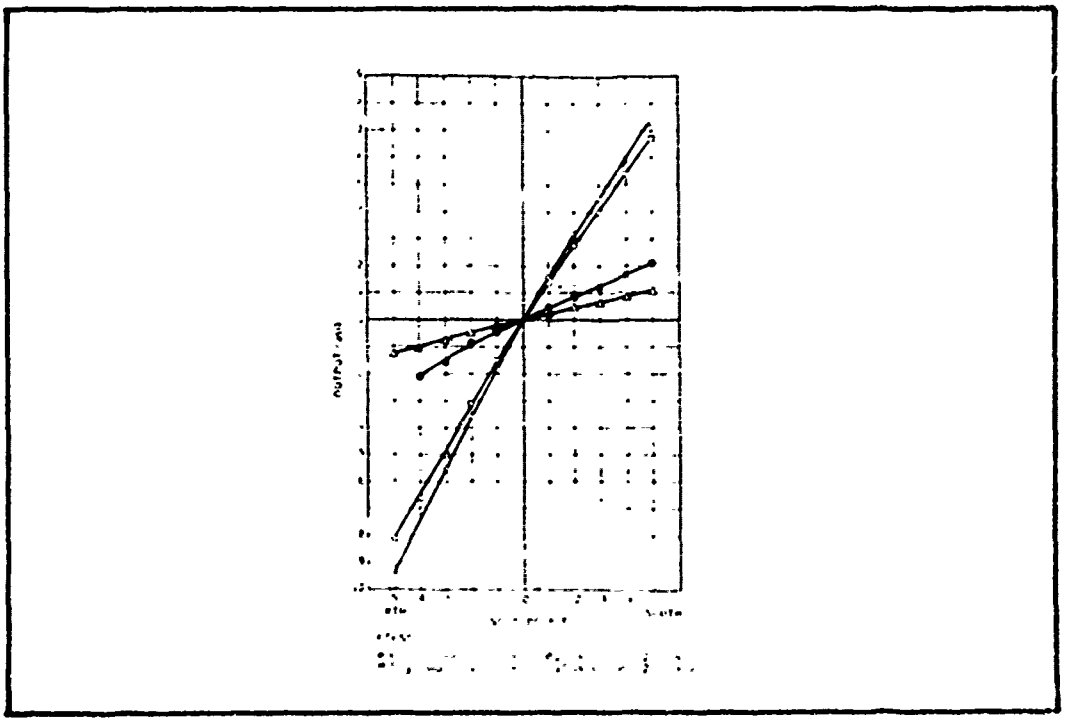


FIGURE 2.119 AVAILABLE DATA: TWO AXIS GYRO - HONEYWELL

2.7.3 Flow Meters

There are three basic types of fluid flow meters (or velocity sensors) currently available. The first employs a free jet traversing between a supply jet and two total head pickup tubes or receivers. The operation of the sensors is dependent upon the jet entrainment of the surrounding fluid, which causes the jet issuing from the nozzle to be deflected to one or the other of the pickup tubes. By monitoring of pressure differential across the pickup tubes, it can be shown that the cross flow of the measured velocity is directly proportional to the pressure differential. Accuracies are claimed in the order of 2% of maximum reading, and experiments have shown that the dependency of differential pressure varies linearly with cross flow air velocity.

The second type of fluidic flow meter employs a basic fluidic oscillator such as shown in Figure 2.120. With this concept, oscillations are detected by a flush mounted sensor (electromagnetic) and are amplified by electronics to provide a digital pulsed output. Basically, the device is nothing more than a fluidic oscillator with the feedback passage essentially controlling the frequency of oscillation for a given flow velocity. Experiments have shown that the sensor yields a relatively noise free signal with accuracies claimed in the order of $\pm 0.2\%$ of the actual flow rate. The third type can also be considered an oscillator, since it employs an ultrasonic means of measuring vortex shedding about a submerged strut.

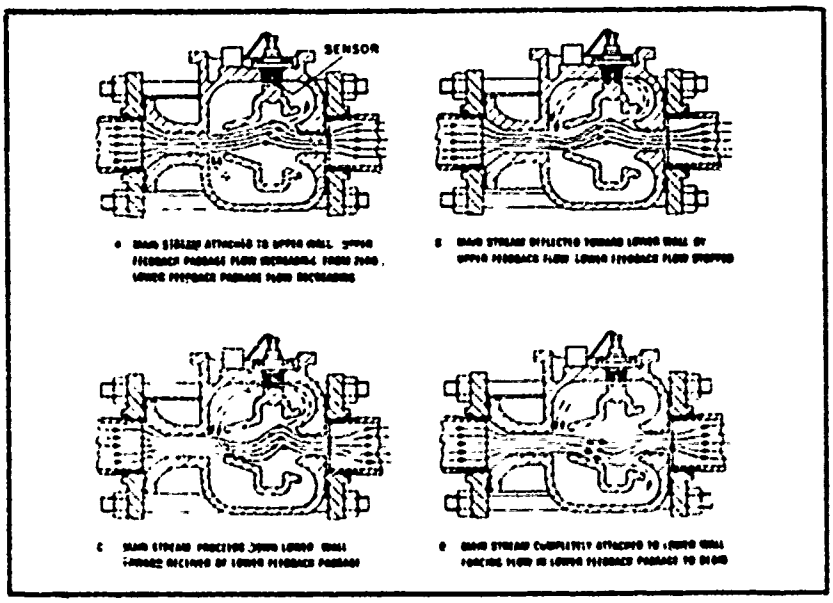


FIGURE 2.120 OSCILLATING FLOW METER DIAGRAM

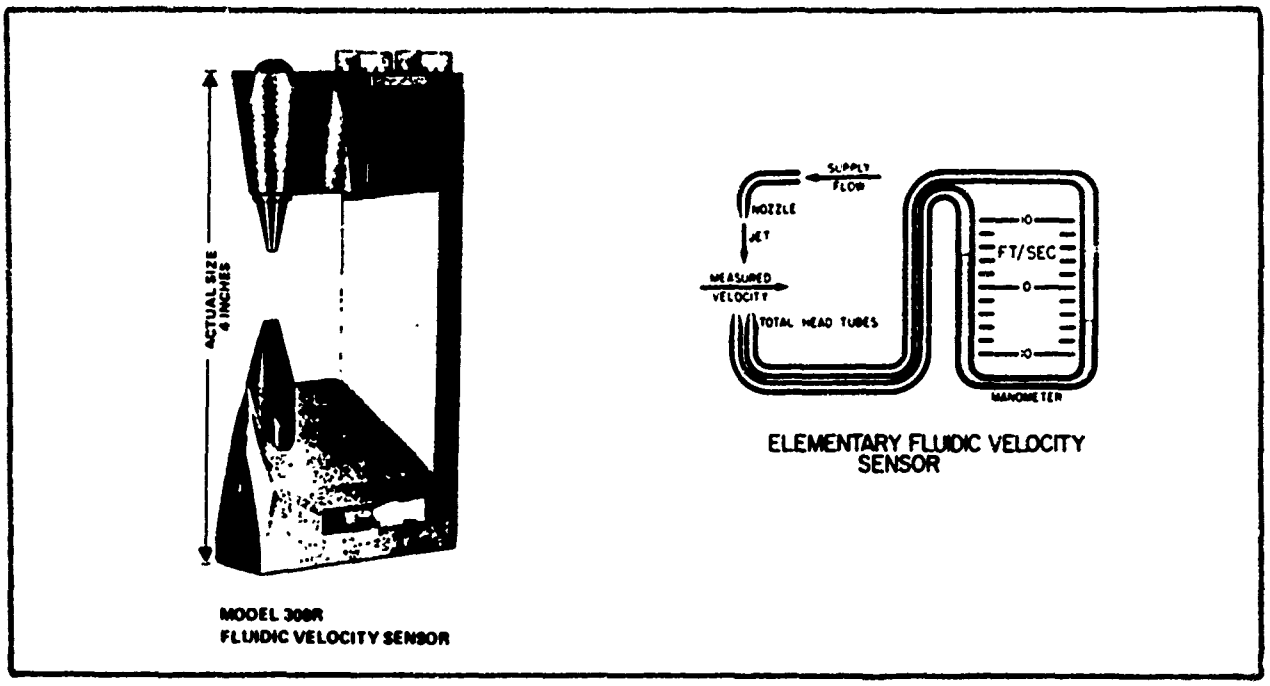


FIGURE 2.121 JET DEFLECTION VELOCITY SENSOR-FLUIDYNAMIC DEVICES LTD.

GENERAL INFORMATION

TYPE OF SENSOR: Velocity MOVING PARTS: None

PRINCIPLE OF OPERATION: Jet deflection creates differential pressure proportional to $v\sqrt{\rho}$

DATA SOURCE: FluiDynamic Devices Ltd. Brochure

PRIMARY FLUID: Gas, liquid INTERFACE: Gas-Gas, Liquid-Liquid

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -200°F to 1200°F PRESSURE: Not critical

POWER SUPPLY FILTRATION: N A

EFFECT ON MEASURED QUANTITY: Causes negligible pressure drop

SENSITIVITY TO:

SHOCK: None NOISE: None

ACCELERATION: None VIBRATION: None

REFERENCE: Ambient

ORDERING INFORMATION

MANUFACTURER OR SOURCE: FluiDynamic Devices Limited
3216 Lentworth Drive
Mississauga, Ontario L4X2G1

POINT OF CONTACT: P.W. Gooch (416) 625-9501

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $v\sqrt{\rho} \rightarrow \Delta P$

FREQUENCY RESPONSE:	U		TIME RESPONSE:	1 ms
SUPPLY: PRESSURE-Minimum:	15 psig		Maximum:	80 psig
FLOW-Minimum:	0.3 scfm		Maximum:	1 scfm
POWER-Minimum:	14.6 W		Maximum:	260 W
OUTPUT: PRESSURE-Minimum:	See Fig.2.122		Maximum:	See Figure 2.122
FLOW-Minimum:	" "		Maximum:	" "
POWER-Minimum:			Maximum:	
CONTROL: PRESSURE-Minimum:	N/A			
IMPEDANCE:	N/A			
SCALING ABILITY:	Yes			
LINEARITY: RANGE:	100 fps		ACCURACY:	2% FS

MEASUREMENT RANGE: Threshold 0.5 fps; Maximum 60 fps

HYSTERESIS: None GAIN: 0.0361 to 0.054 psid/fps

OUTPUT SIGNAL: Differential pressure proportional to velocity

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: 75 at FS EXPECTED LIFE: Indefinite

MTBF: U MCBF: U MTTR: U

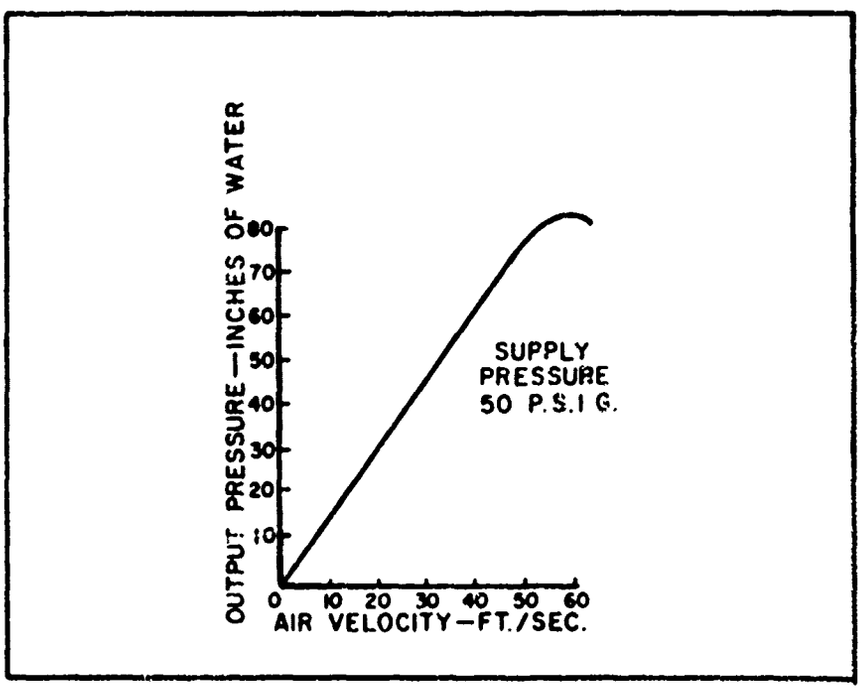


FIGURE 2.122 AVAILABLE DATA-JET DEFLECTION VELOCITY SENSOR-FD.D, LTD.

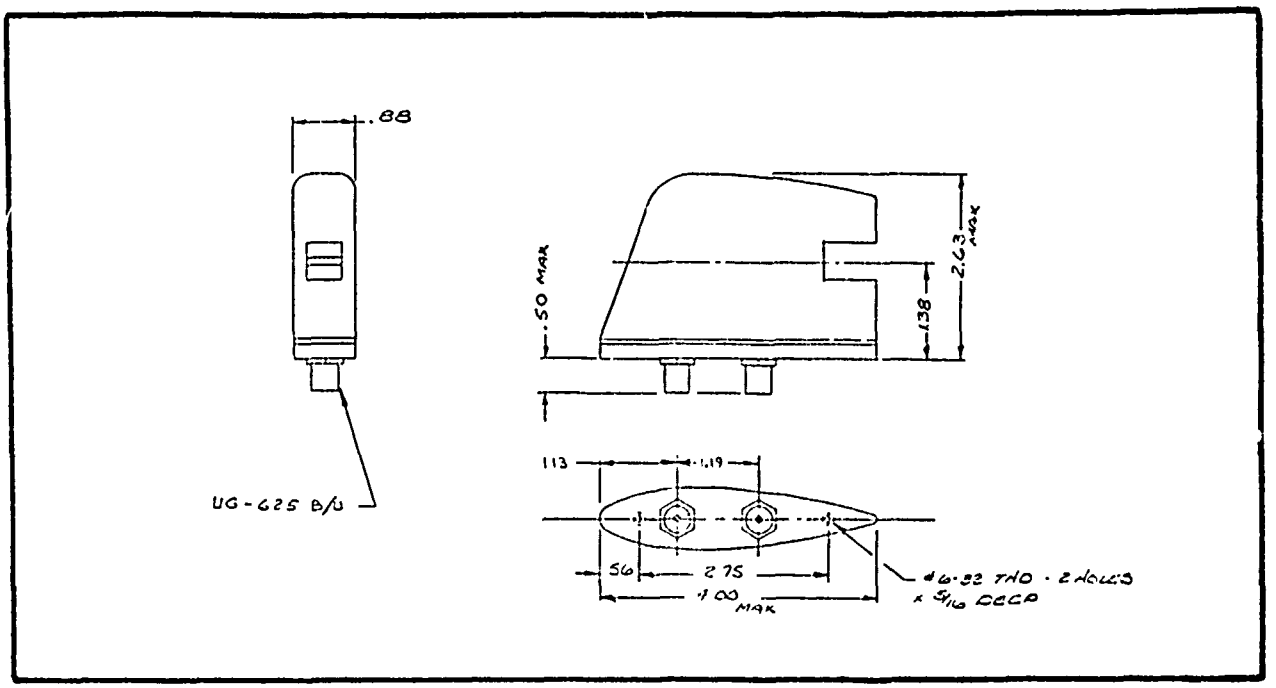


FIGURE 2.123 ULTRASONIC VELOCITY SENSOR-J-TEC

GENERAL INFORMATION

TYPE OF SENSOR: Velocity MOVING PARTS: None

PRINCIPLE OF OPERATION: Ultrasonic Measurement of Vortex Shedding

DATA SOURCE: J-TEC Brochure: Model # VA-210/220

PRIMARY FLUID: Air, Water INTERFACE: Electronic

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U PRESSURE: U

POWER SUPPLY FILTRATION: None Required

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Strouhal Frequency

ORDERING INFORMATION

MANUFACTURER OR SOURCE: J-TEC Associates, Inc,
317 8th Avenue, S.E.
Cedar Rapids, Iowa 52401

POINT OF CONTACT: Mr. Douglas Beadle (319) 366-7511

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

INPUT: Flow Field about strut-to 200 knots

OUTPUT: Electronic frequency or voltage

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: 2-200 knots ACCURACY: ± 1% Full Scale

THRESHOLD SENSITIVITY; .25" per sec

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: 70 Hz/knot (freq) or 50 max knot (analog)

CROSS SENSITIVITY EFFECTS: None to ± 30°pitch and ± 15°Yaw

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

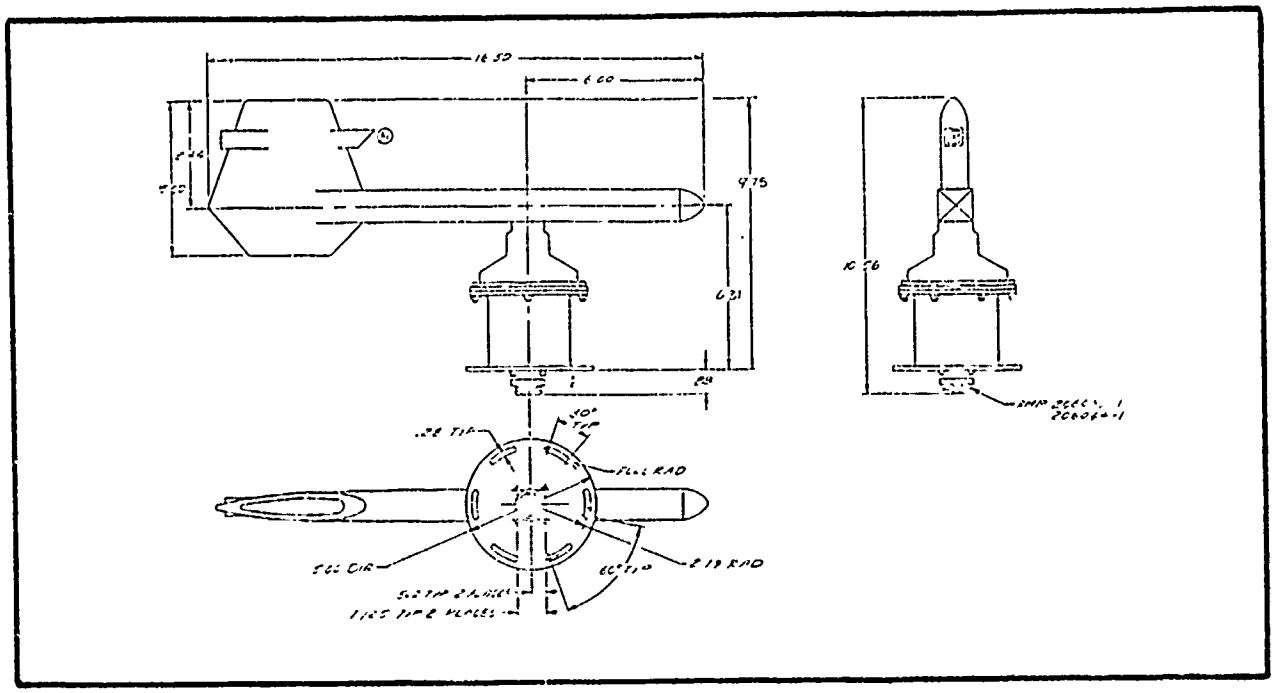


FIGURE 2.124 ULTRASONIC VELOCITY SENSOR-J-TEC

GENERAL INFORMATION

TYPE OF SENSOR: Velocity MOVING PARTS: None

PRINCIPLE OF OPERATION: Ultrasonic Measurement of Vortex Shedding

DATA SOURCE: J-TEC Brochure: Models A-213/014

PRIMARY FLUID: Air INTERFACE: Electronic

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 20° to 200°F PRESSURE: U

POWER SUPPLY FILTRATION: None Required

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Strouhal Frequency

ORDERING INFORMATION

MANUFACTURER OR SOURCE: J-TEC Associates Inc.
317 7th Avenue, S.E.
Cedar Rapids, Iowa 52401

POINT OF CONTACT: Mr. Douglas Beadle (319) 366-7511

PRODUCT AVAILABILITY: Off-the-Shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

INPUT: Flow Field about strut, to 3000 fPM

OUTPUT: Electronic frequency or voltage

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: 75 to 3000 FPM* ACCURACY: ± 2%

THRESHOLD SENSITIVITY: 0.5" per sec

HYSTERESIS: U GAIN: NA

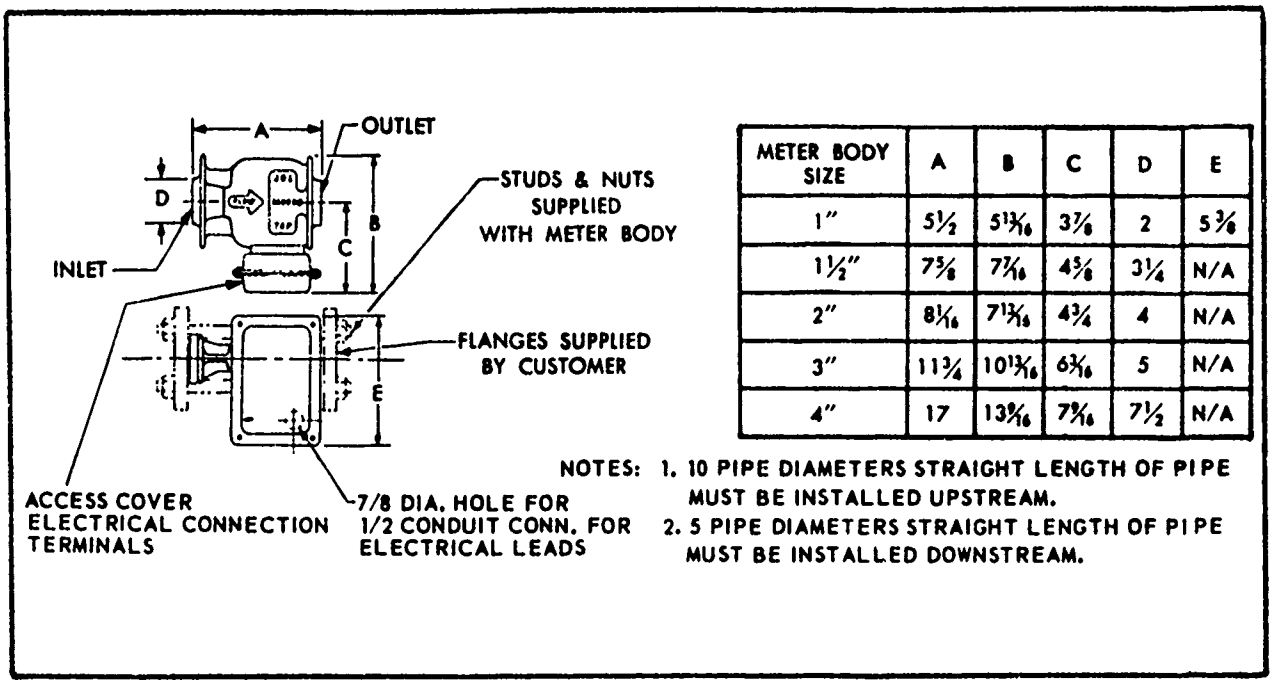
OUTPUT SIGNAL: 0.25 Hz/FPM (Freq) or 2.5 v/FPM (Analog)

CROSS SENSITIVITY EFFECTS: Yaw or pitch has no effect

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* 150-10000 FPM Extended Range



METER BODY SIZE	A	B	C	D	E
1"	5½	5 13/16	3⅞	2	5⅜
1½"	7⅝	7 11/16	4⅝	3¼	N/A
2"	8 1/16	7 13/16	4¾	4	N/A
3"	11¾	10 13/16	6 3/16	5	N/A
4"	17	13 9/16	7 9/16	7½	N/A

NOTES: 1. 10 PIPE DIAMETERS STRAIGHT LENGTH OF PIPE MUST BE INSTALLED UPSTREAM.
2. 5 PIPE DIAMETERS STRAIGHT LENGTH OF PIPE MUST BE INSTALLED DOWNSTREAM.

FIGURE 2.125 FLOW METER-MOORE PRODUCTS

GENERAL INFORMATION

TYPE OF SENSOR: Flow Meter

MOVING PARTS: None

PRINCIPLE OF OPERATION: Fluidic Oscillator, frequency dependant on volume flow rate

DATA SOURCE: Moore Products Brochure

PRIMARY FLUID: Liquids

INTERFACE: Liquid-Electrical

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: $0 < T < 250^{\circ}F$ (meter body)
$-22 < T < 122^{\circ}F$ (converter)

PRESSURE: 1" meter body, 1500 psi
1-1/2" meter body, 600 psi
2",3",4" m.b., 150 psi

POWER SUPPLY FILTRATION:

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: None

NOISE: None

ACCELERATION: None

VIBRATION: No.

REFERENCE: Frequency of oscillation

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Moore Products Co.
Sumneytown Pike
Spring House, PA. 19477

POINT OF CONTACT: Robert B. Adams (215) 646-7400

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $385.00, Model 141086S, 600 psi rating, up to
$865.00, Model 144081S, 150 psi rating

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

THROUGHPUT: 1" meter body, 16 thru 50 gpm
4" meter body, 345 thru 950 gpm

OUTPUT: PRESSURE-Minimum: See Figure 2.126
FLOW-Minimum: " " "
POWER-Minimum:

CONTROL: PRESSURE-Minimum: NA

IMPEDANCE: NA

SCALING ABILITY: Yes

LINEARITY: RANGE: Elec., within ± 1% FS
Pneu., within ± 1.25% FS

ACCURACY: Elec., ± 0.2% of Reading
Pneu., ± 0.25% FS

HYSTERESIS: U

GAIN: U

OUTPUT SIGNAL: Electrical Current

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: U

MTBF: U

MCBF: U

MTTR: U

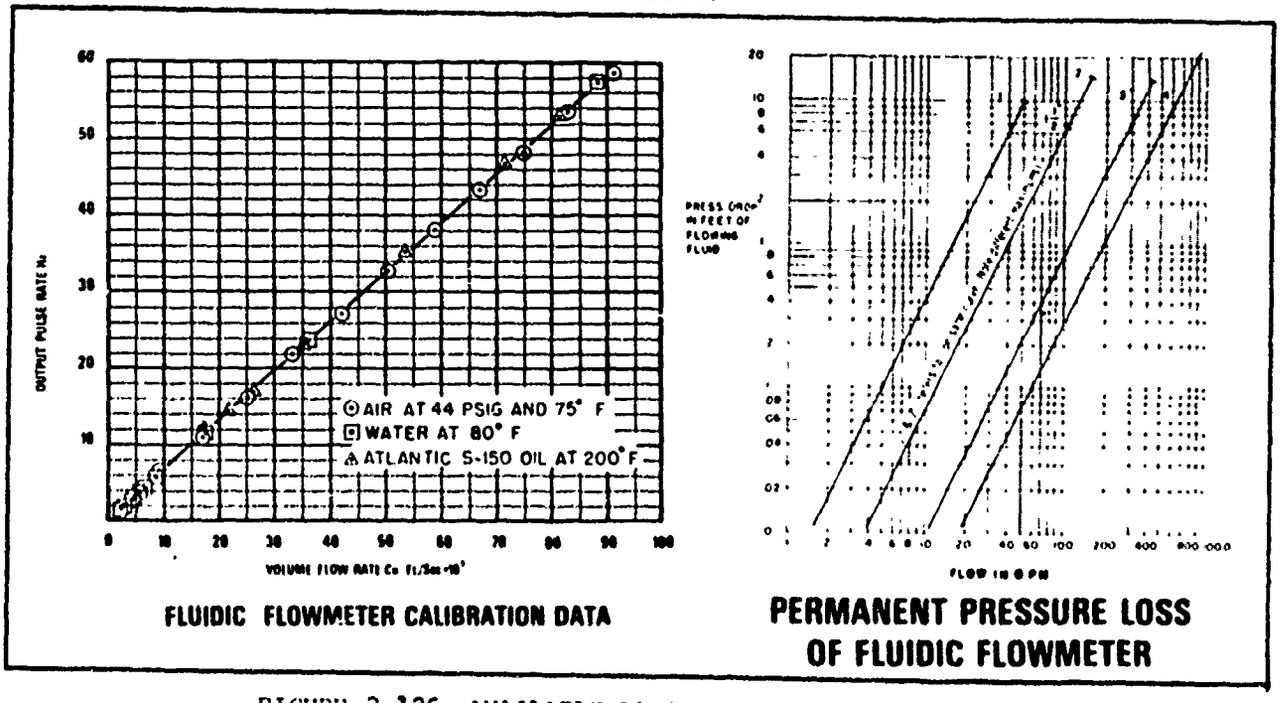


FIGURE 2.126 AVAILABLE DATA-FLOW METER-MOORE PRODUCTS

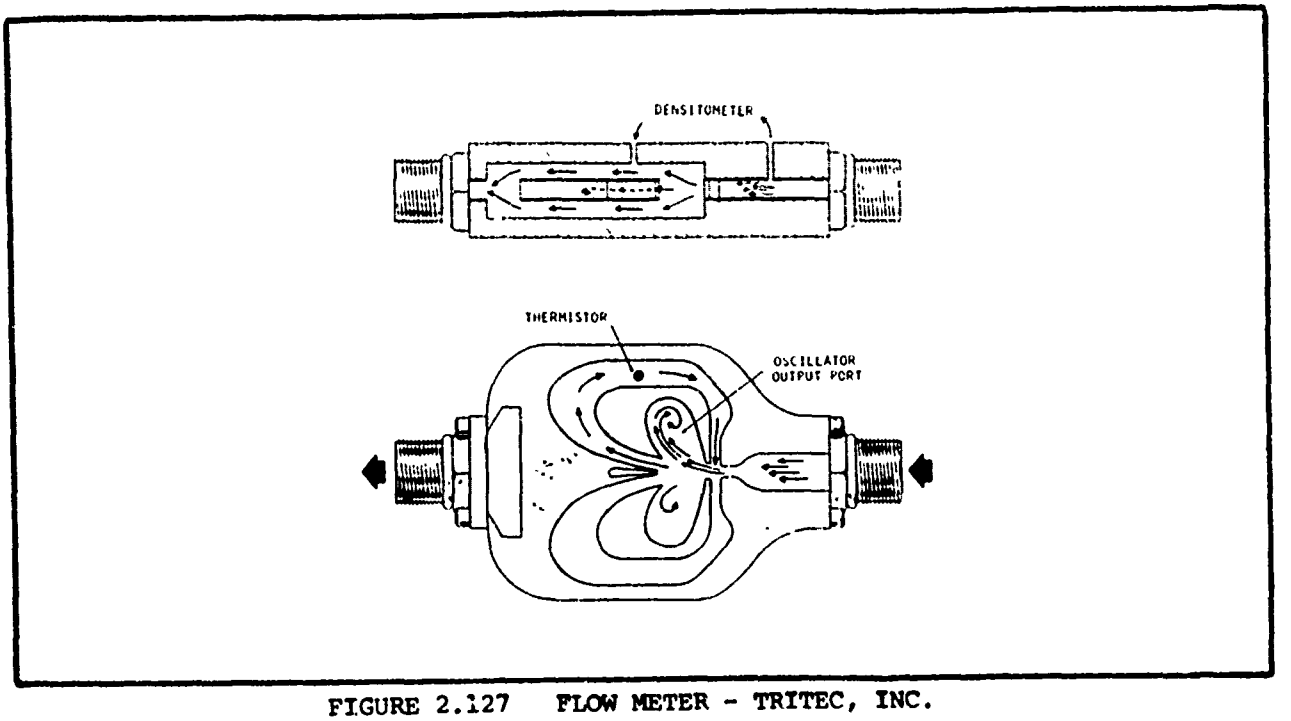


FIGURE 2.127 FLOW METER - TRITEC, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Flowmeter

MOVING PARTS: None

PRINCIPLE OF OPERATION: Fluidic proportional oscillator (frequency measured by thermistor)

DATA SOURCE: G.E. Report "Fluidic Mass Fuel Flow Transmitter" Phase I, Dec.'75

PRIMARY FLUID: Air, Water

INTERFACE: Electronic

READOUT PROVIDED: Yes

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 190° C

PRESSURE: 2000 psi

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: None (Tested 3 axis)

REFERENCE:

ORDERING INFORMATION

MANUFACTURER OR SOURCE: TriTec, Inc.
615 S. Frederick Avenue
Gaithersburg, MD 20760

POINT OF CONTACT: Mr. Vincent Neradka

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: $f = \frac{1}{2(\tau_v + \tau_a)} \left[1 - \frac{\phi_f}{\pi}\right]^{*}$

FREQUENCY RESPONSE: U TIME RESPONSE: 1 second

SUPPLY: PRESSURE- As required

OUTPUT: PRESSURE- U

IMPEDANCE: U

SCALING ABILITY: Yes

LINEARITY: RANGE: See Figure 2.128 ACCURACY: ± 1.0%

SENSING RANGE: 200 to 5,000 pph** 100:1)

HYSTERESIS: U GAIN: 49.75 pph/Hz**

OUTPUT SIGNAL: Electronic pulsed frequency (pressure optional)

CROSS SENSITIVITY EFFECTS: Slight temperature shift

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

* f = Frequency
τ_v = Equivalent Transport Lag due to fluid velocity
τ_a = Acoustic Transport Delay
ϕ_f = Phase Lag of feedback network

** pph = Pound per Hour

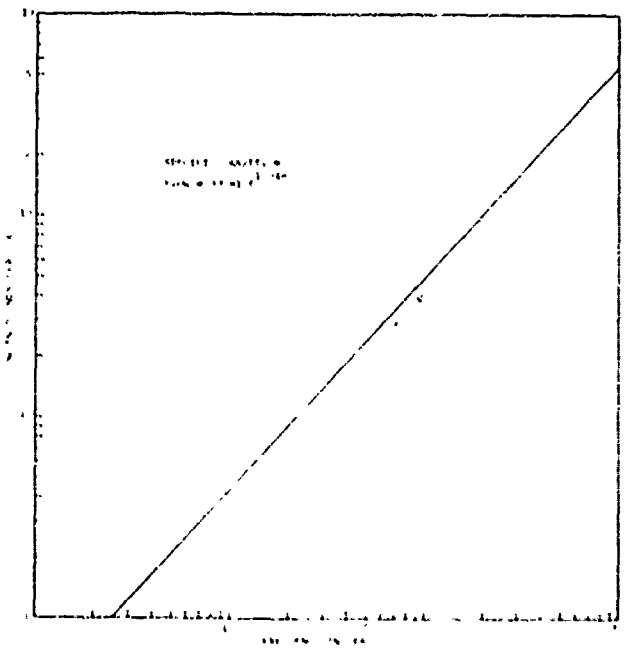


FIGURE 2.128 AVAILABLE DATA: FLOW METER - TRITEC, INC.

2.7.4 Pressure Ratio Sensor

The pressure ratio sensor is a device that can be used to monitor a preset differential pressure. There are several variations, but most consist of a two-part mechanism having both a fluidic to mechanical pressure sensing section and a mechanical to electrical transducer. Only one commercially available pressure ratio sensor has no moving mechanical parts. It employs a vortex "whistle" and utilizes a piezoelectric crystal to monitor the vortex "whistle" frequency.

The mechanical type is composed of two stages of fluidics: a receiver and an amplifier. Typically, each is suspended on two soft diaphragms to form a leakless push-pull piston. Manufacturers claim accuracy to $\pm$ 3.5% of reading and time of response in the order of 15 ms. Several versions of these devices are shown in Figure 2.129.

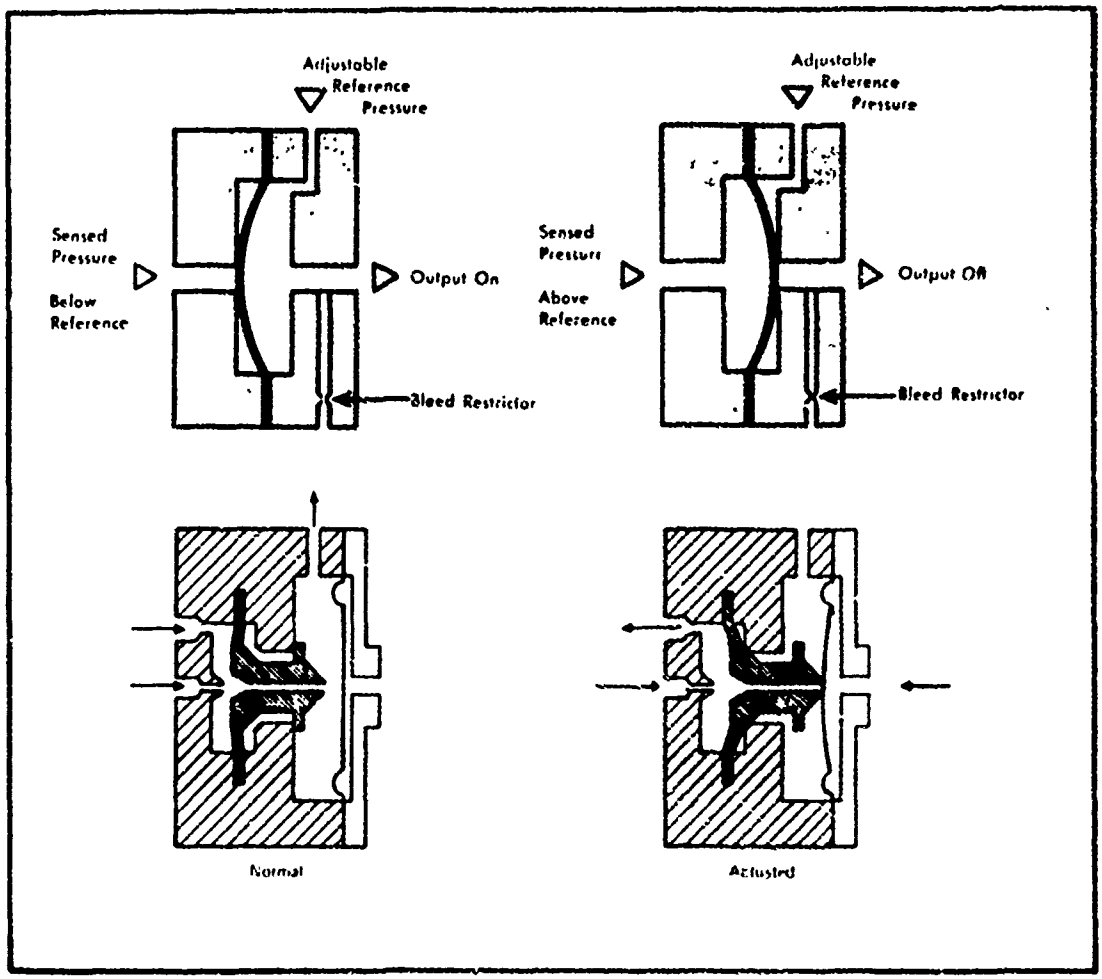


FIGURE 2.129 VARIATIONS OF BASIC PRESSURE RATIO SENSOR

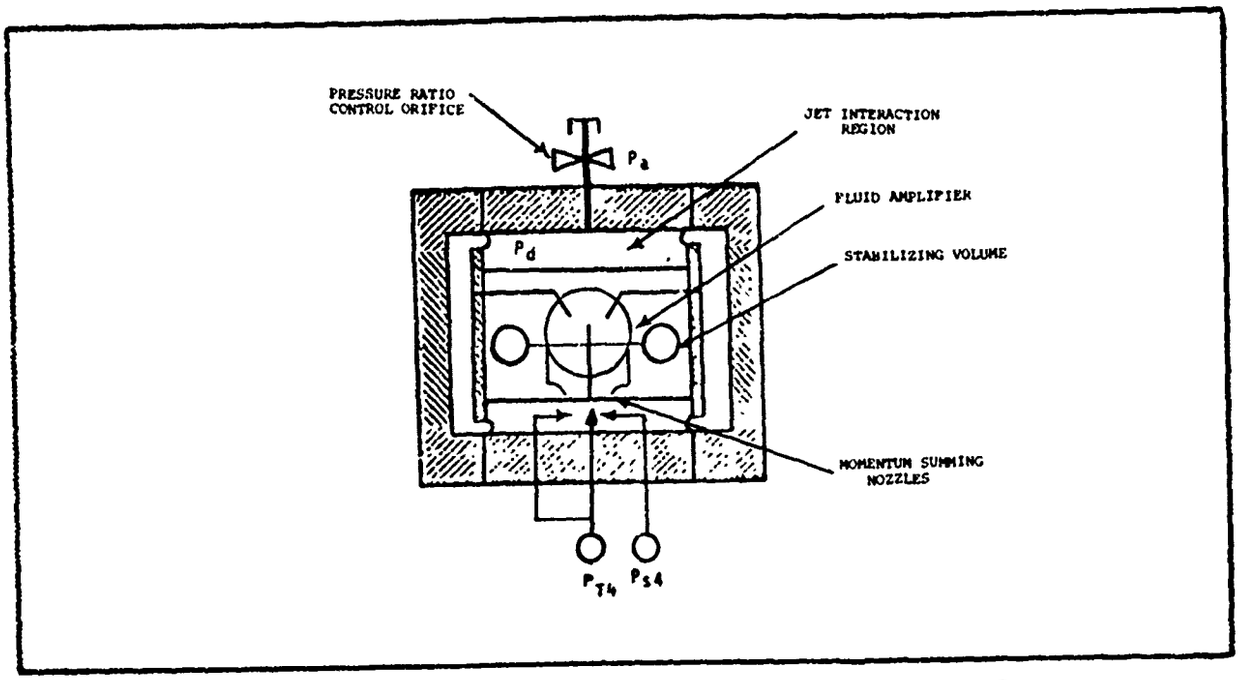


FIGURE 2.130 PRESSURE RATIO SENSOR-CHANDLER EVANS, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Pressure Ratio

MOVING PARTS: Yes (diaphragms and springs)

PRINCIPLE OF OPERATION: Pressure deflects diaphragms, LVDT* measures output

DATA SOURCE: Chandler Evans Inc.

PRIMARY FLUID: Air

INTERFACE: Fluid/mechanical/electrical

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: U

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: U

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: 0.5%/g

VIBRATION: U

REFERENCE: Spring force of diaphragm

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Chandler Evans Inc.
Control Systems Div.
Charter Oak Blvd.
West Hartford, Conn. 06101

POINT OF CONTACT: Mr. R.F. Kampe (203) 236-0651

PRODUCT AVAILABILITY: Special Order

COST: U

* Linear Variable Differential Transformer

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: TIME RESPONSE: 0.015 sec

SUPPLY: PRESSURE- 50 psia Maximum: 180 psia

OUTPUT: PRESSURE- U

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: 0.1 to 0.3 Δ P/P ACCURACY: ± 3.5% of reading

TOTAL SENSING RANGE: MINIMUM OBJECT SIZE:

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Electrical via Linear Variable Differential Transducer

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

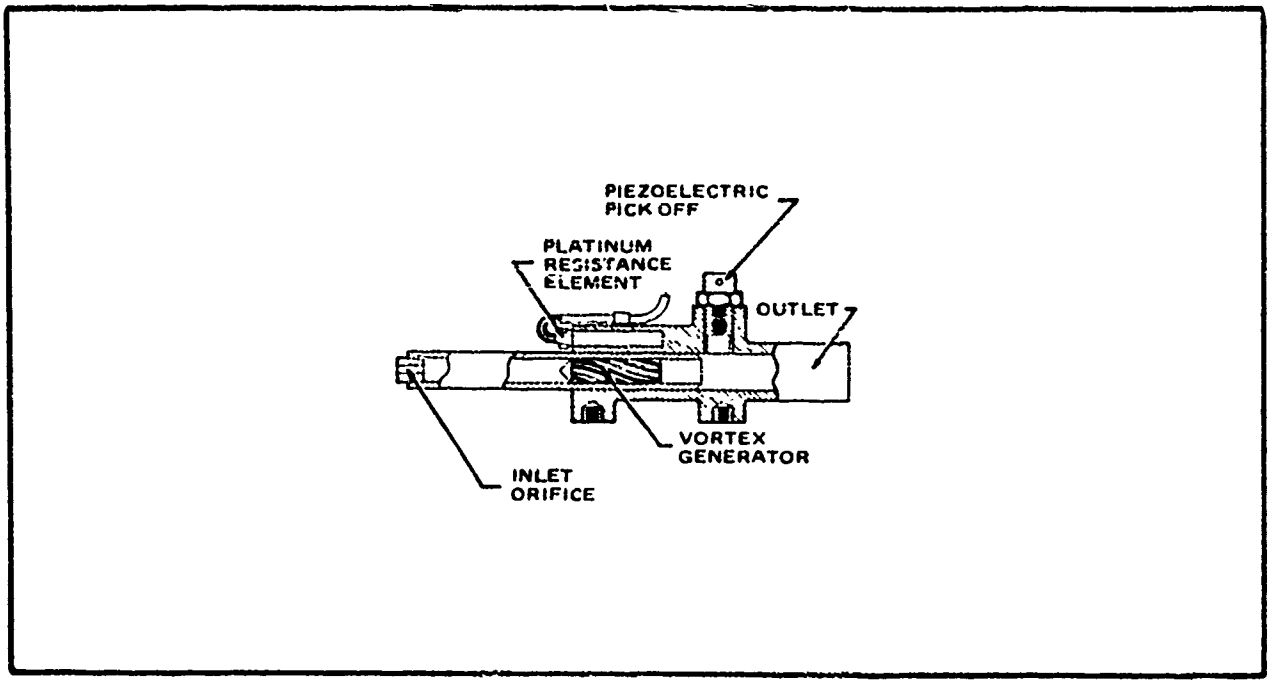


FIGURE 2.131 PRESSURE RATIO SENSOR - HONEYWELL

GENERAL INFORMATION

TYPE OF SENSOR: Pressure Ratio

MOVING PARTS: None

PRINCIPLE OF OPERATION: Vortex Whistle

DATA SOURCE: Honeywell Brochure: 29051-3027

PRIMARY FLUID: Air

INTERFACE: Piezoelectric crystal

READOUT PROVIDED: Yes, gauge

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 2000° F

PRESSURE: 75,000 ft altitude

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: No per MIL-STD 810B Curve L; 20 - 40 g's

REFERENCE: Ambient

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Honeywell, Inc.
2600 Ridgway Parkway
Minneapolis, Minn. 55413

POINT OF CONTACT: Mr. James Hedeen (612) 331-4141

PRODUCT AVAILABILITY: Off-the-shelf

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: Frequency $\simeq KV_s \left(\frac{\Delta P}{P_2}\right)^{1/2}$ (See legend below)*

FREQUENCY RESPONSE: U TIME RESPONSE: 10 ms

SUPPLY: PRESSURE- 1 - 10 psid

OUTPUT:

IMPEDANCE: U

SCALING ABILITY: No

LINEARITY: RANGE: -65° to 500° F ACCURACY: ± 2%

TEMP. SENSING RANGE: -65° to 1400° F

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: Pneumatic converted to electric via piezoelectric crystal.

CROSS SENSITIVITY EFFECTS: Some Δt effects

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

*TRANSFER FUNCTION: K = Constant

ΔP = Differential absolute pressure across whistle

P_2 = Inlet (or exhaust) absolute pressure

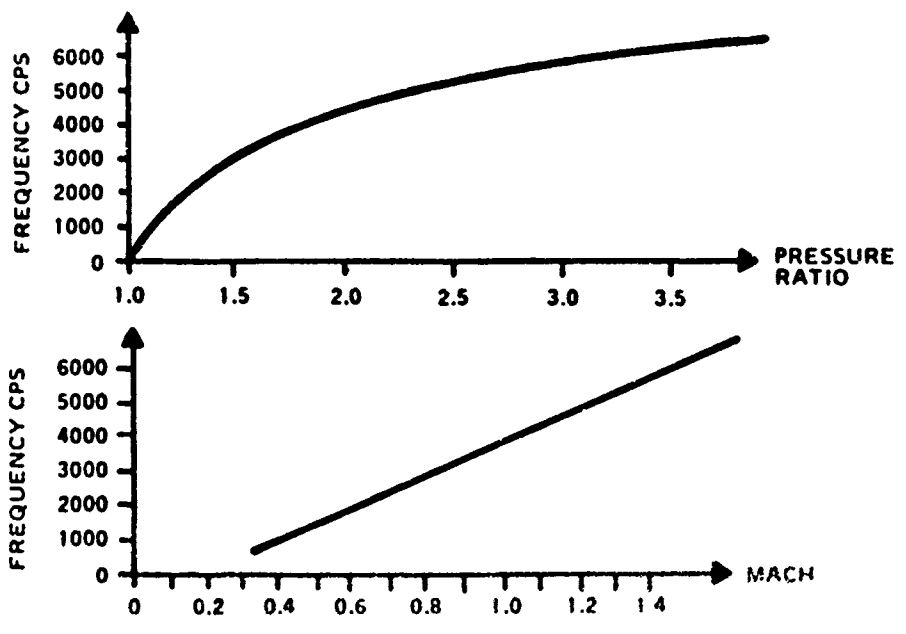


FIGURE 2.132 AVAILABLE DATA: PRESSURE RATIO SENSOR - HONEYWELL

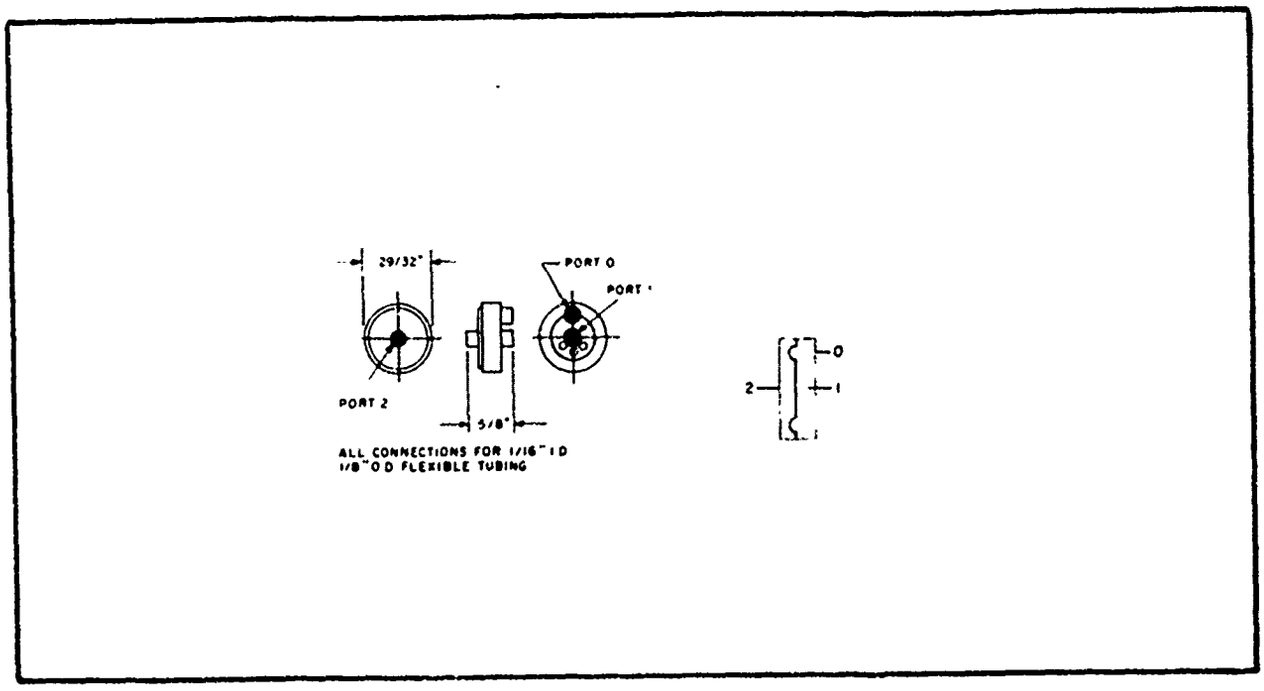


FIGURE 2.133 PRESSURE RATIO SENSOR-AIR LOGIC

GENERAL INFORMATION

TYPE OF SENSOR: Pressure

MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Diaphragm Actuated

DATA SOURCE: Air Logic Brochure 8260 Part No. F-4103-20

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 40° to 100°F

PRESSURE: U

POWER SUPPLY FILTRATION: 5 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: U

REFERENCE: Ambient Air

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Air Logic Div.
Fred Knapp Engraving Co., Inc.
5102 Douglas Ave.,
Racine, Wisc. 53402

POINT OF CONTACT: Mr. Donald Kaske (414) 639-3941

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $5.25 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: U

SUPPLY: PRESSURE- 0.5 to 25 psig See Figure 2.134

OUTPUT: PRESSURE- See Figure 2.134

IMPEDANCE: U

SCALING ABILITY: U

LINEARITY: RANGE: See Figure 2.134 ACCURACY: U

PRESSURE SENSING RANGE: See Figure 2.134

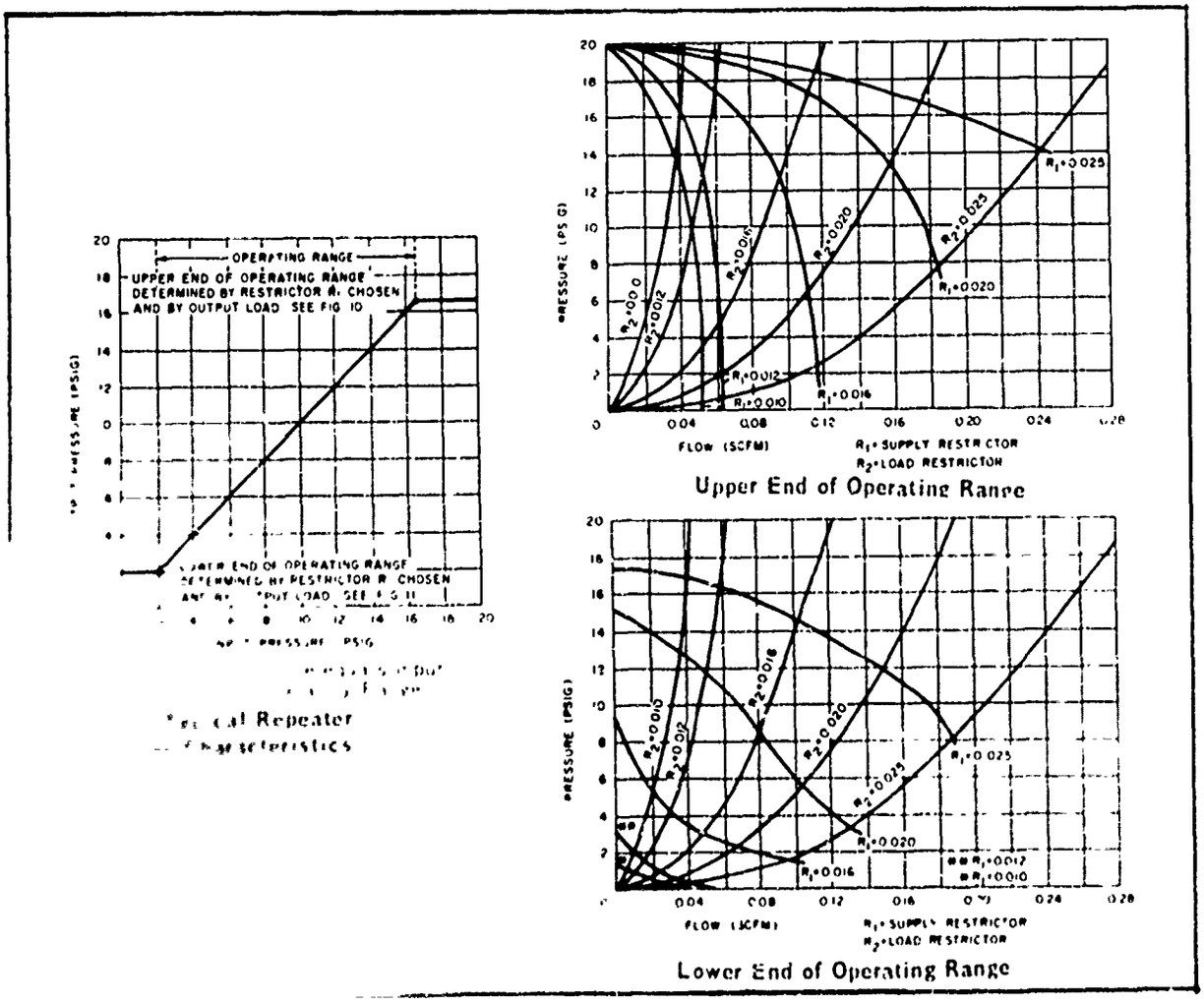
HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Proportional Pressure

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U



...al Repeater

...g Characteristics

...RATIO SENSOR-AIR LOGIC

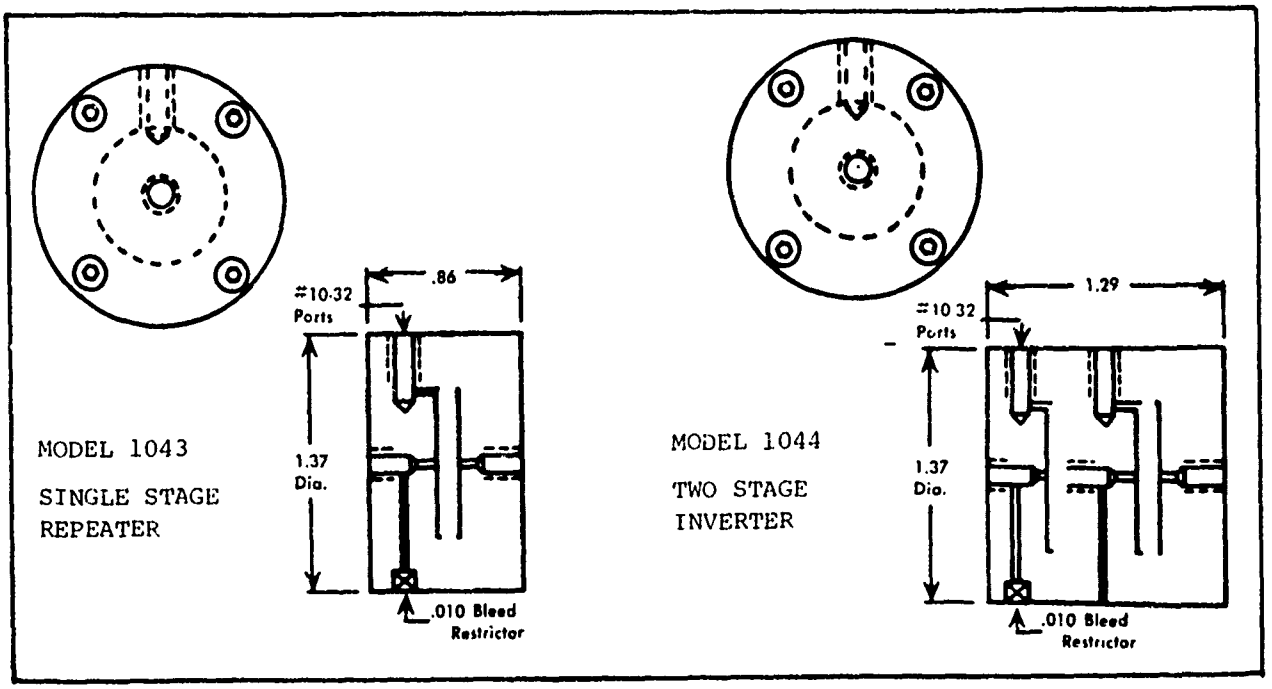


FIGURE 2.135 PRESSURE RATIO SENSORS-NORTHEAST FLUIDICS

GENERAL INFORMATION

TYPE OF SENSOR: Pressure MOVING PARTS: Yes

PRINCIPLE OF OPERATION: Diaphragm Actuated

DATA SOURCE: Northeast Fluidics Brochure Parts # 1043/1044

PRIMARY FLUID: Air, Gas, Liquid INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 32° to 180°F PRESSURE: 150 psi

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: U VIBRATION: U

REFERENCE: Spring Diaphragm

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Northeast Fluidics, Inc.
Clippard Instrument Labs
7390 Colerain Road
Cincinnati, Ohio 45239

POINT OF CONTACT: U (513) 521-4261

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $15.90 (Mod 1043) $21.20 (Mod 1044)

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE:	60 Hz		TIME RESPONSE:	5ms
SUPPLY: PRESSURE-Minimum:	1 psi		Maximum:	150 psi
FLOW-Minimum:	.029 orifice		Maximum:	.029" orifice
POWER-Minimum:	U		Maximum:	U
OUTPUT: PRESSURE-Minimum:	U		Maximum:	U
FLOW-Minimum:	U		Maximum:	U
POWER-Minimum:	U		Maximum:	U
CONTROL: PRESSURE-Minimum:	NA			

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U ACCURACY: U

PRESSURE SENSING: 1-150 psi

HYSTERESIS: U GAIN: NA

OUTPUT SIGNAL: Proportional Pressure

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

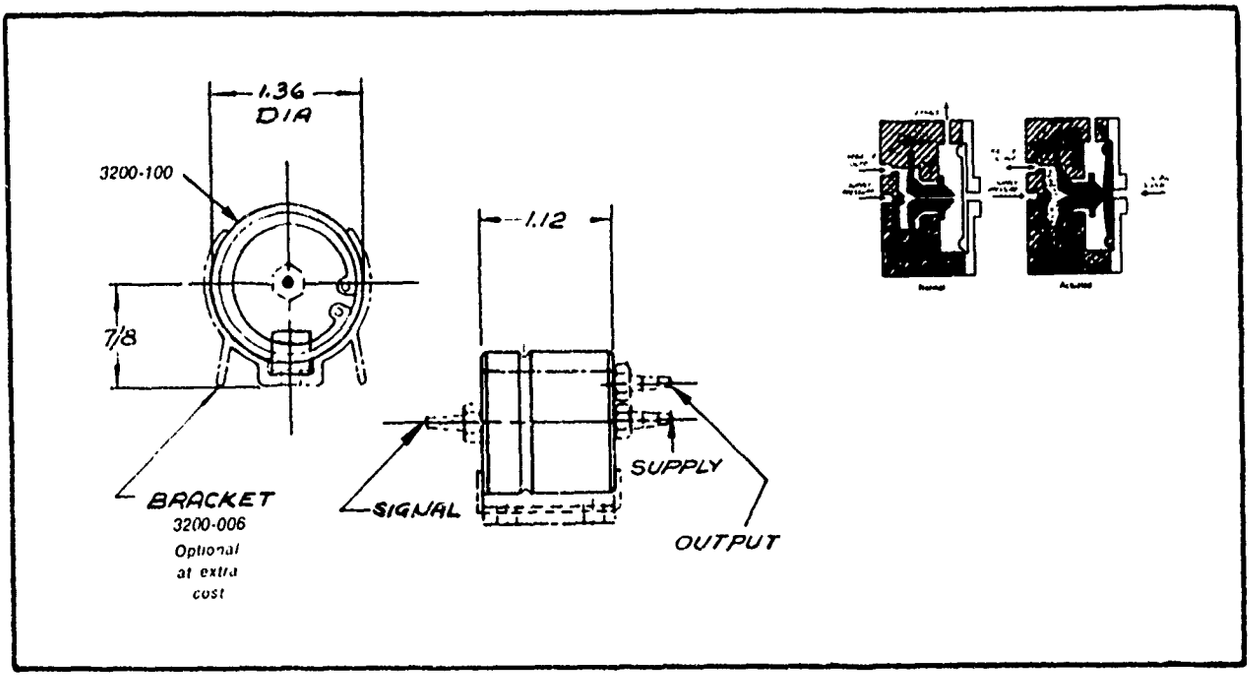


FIGURE 2.136 DIAPHRAGM MOUNTED PRESSURE RATIO SENSOR-NORTHEAST FLUIDICS

GENERAL INFORMATION

TYPE OF SENSOR: Pressure

MOVING PARTS: Yes (Nozzle, Diaphragm)

PRINCIPLE OF OPERATION: Diaphragm Mounted Sensing Nozzle

DATA SOURCE: Northeast Fluidics: Part # 3200

PRIMARY FLUID: Air

INTERFACE: Air-Air

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: 32° to 180°F

PRESSURE: U

POWER SUPPLY FILTRATION: U

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U

NOISE: U

ACCELERATION: U

VIBRATION: U

REFERENCE: Ambient

ORDERING INFORMATION

MANUFACTURER OR SOURCE: Northeast Fluidics, Inc.
Clippard Instrument Labs
7390 Colerain Road
Cincinnati, Ohio 45239

POINT OF CONTACT: U (513) 521-4261

PRODUCT AVAILABILITY: Off-the-Shelf

COST: $23.00 each

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U

TIME RESPONSE: U

SUPPLY: PRESSURE- See Figure 2.137

OUTPUT: PRESSURE- See Figure 2.137

IMPEDANCE: U

SCALING ABILITY: NA

LINEARITY: RANGE: U

ACCURACY: U

MINIMUM SENSING PRESSURE: .05 psi

MAXIMUM SENSING PRESSURE: 1 psi

HYSTERESIS: U

GAIN: U

OUTPUT SIGNAL: Flow- See Figure 2.137

CROSS SENSITIVITY EFFECTS: None

S/N RATIO: U

EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

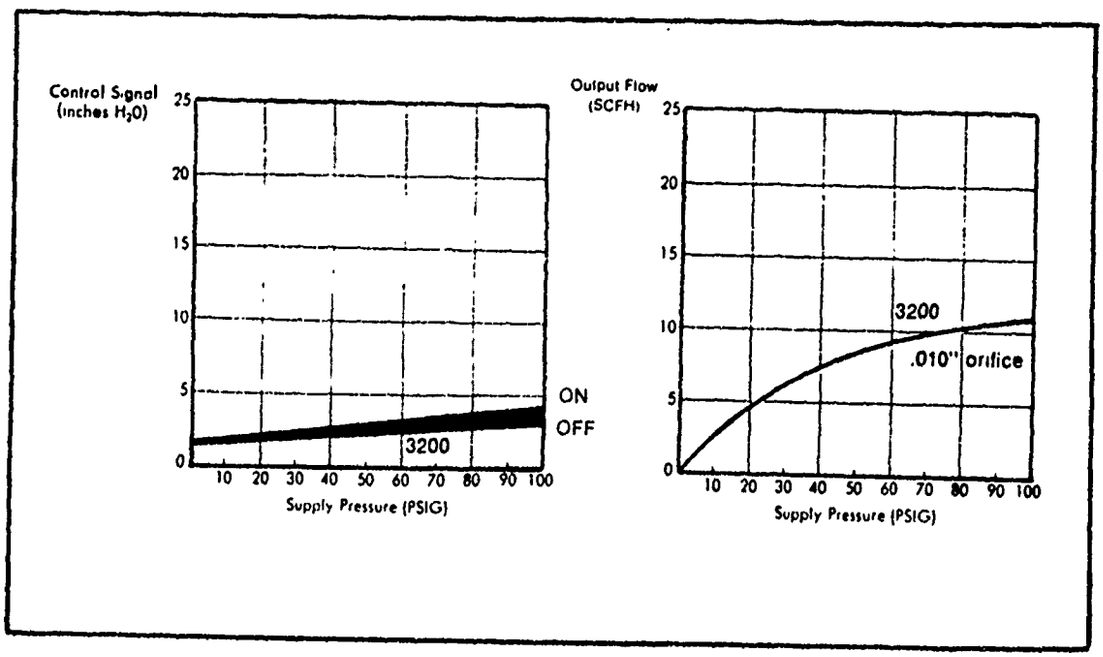


FIGURE 2.137 AVAILABLE DATA: PRESSURE RATIO SENSOR-NORTHEAST FLUIDICS

2.7.5 Electronic/Fluidic Transducer

This device can be considered either a sensor or an interface device. It employs a bistable amplifier with two cylindrical heating wires of equal diameter located in the power nozzle of the amplifier. The principle of operation is depicted in Figure 2.138 . Two heating wires are positioned so that they are symmetrical with respect to the centerline of the channel. If the velocity profile upstream of the wires is uniform (and no heat is transmitted to either wire), then the downstream velocity profile also remains symmetrical with respect to centerline of the channel (see Figgure 2.138a). When a current is passed through wire A, its temperature increases rapidly, and the resistance to the flow of fluid around wire A increases (i.e., the wire's effective diameter increases). Thus, more flow is diverted into the region around wire B, resulting in the velocity profile shown in Figure 2.138b. The amplifier can also operate as a bistable element since it is provided with standard controls. Claims of manufacturers include the fact that the unit will respond in about 50 ms and is insensitive to accelerations.

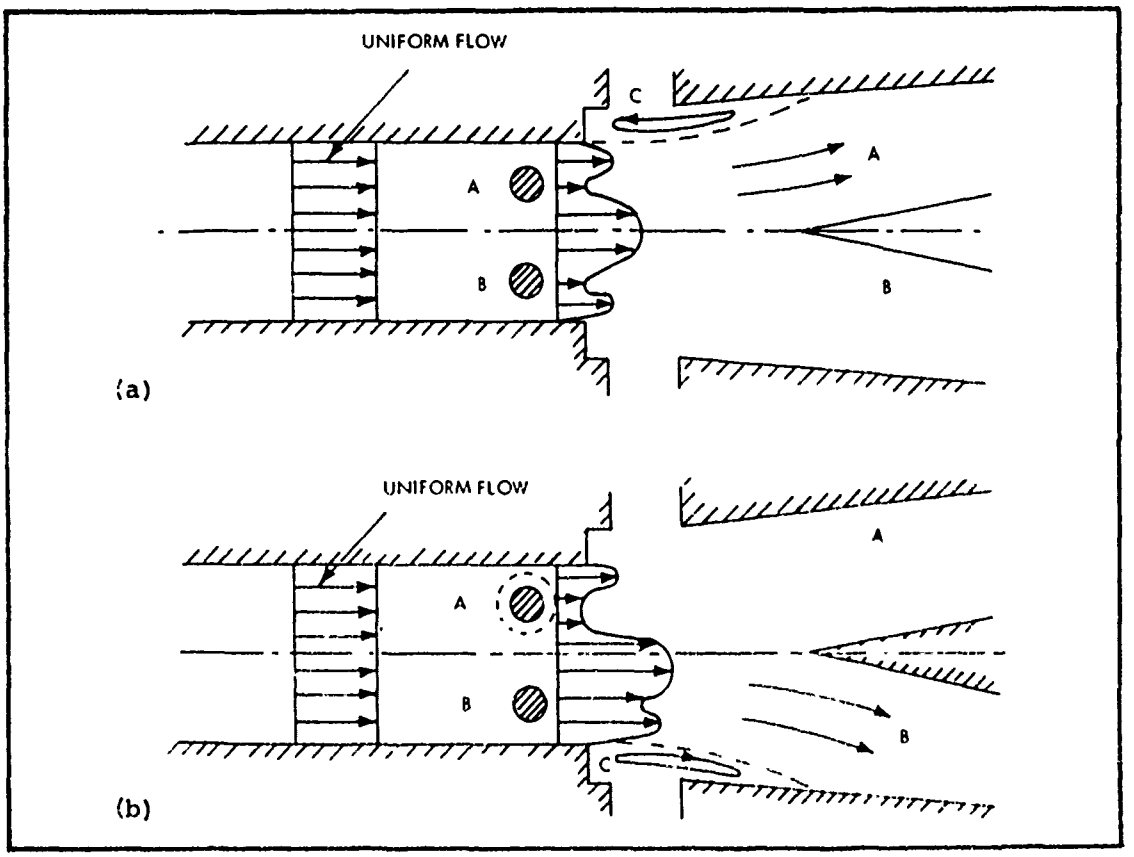


FIGURE 2.138 EF TRANSDUCER - PRINCIPLE OF OPERATION

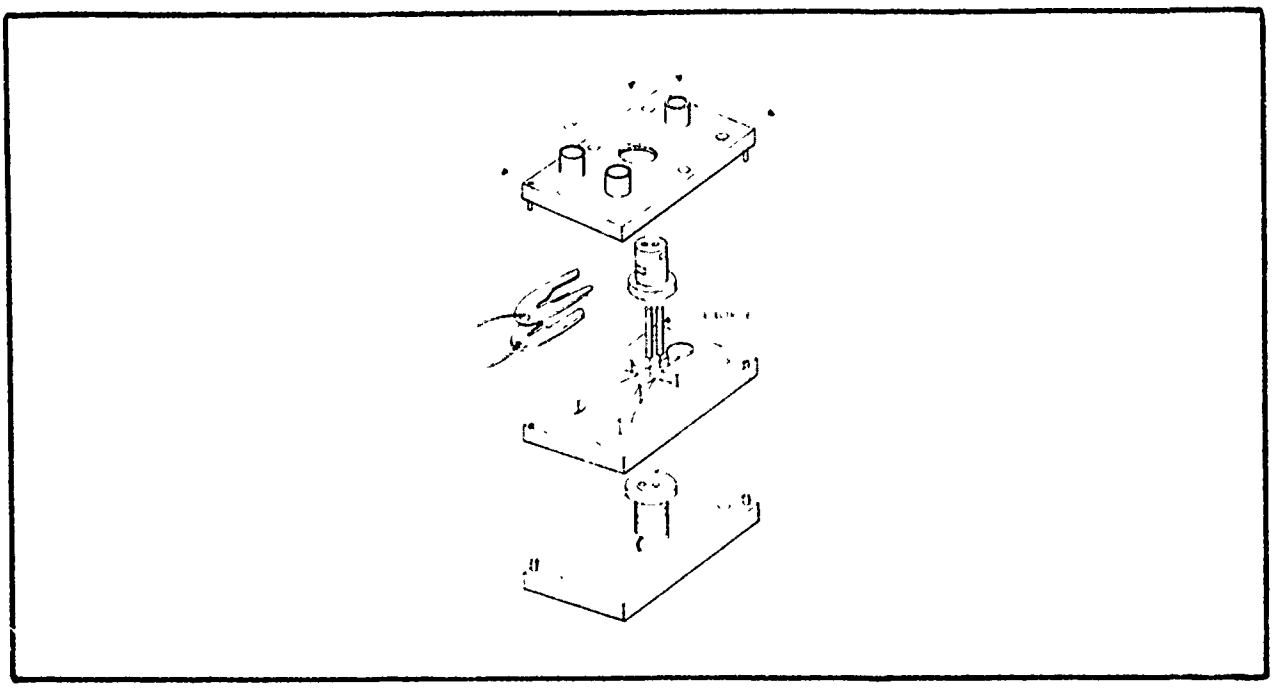


FIGURE 2.139 EF TRANSDUCER - EMX ENGINEERING, INC.

GENERAL INFORMATION

TYPE OF SENSOR: Electric Current MOVING PARTS: None

PRINCIPLE OF OPERATION: Heated wires change power jet profile

DATA SOURCE: "Electric to Fluidic Interface Device" by C.Anagnost & M.Desantis Picatinny Arsenal (4/72)

PRIMARY FLUID: Air INTERFACE: Electric

READOUT PROVIDED: None

ENVIRONMENTAL LIMITATIONS

TEMPERATURE: -50° to 120°F PRESSURE: 15 psig

POWER SUPPLY FILTRATION: 10 micron

EFFECT ON MEASURED QUANTITY: None

SENSITIVITY TO:

SHOCK: U NOISE: U

ACCELERATION: None VIBRATION: U

REFERENCE: NA

ORDERING INFORMATION

MANUFACTURER OR SOURCE: EMX Engineering, Inc.
Box 216-216 Little Falls Road
Cedar Grove, NJ 07009

POINT OF CONTACT: Mr. Anthony Corrado (201) 239-4300

PRODUCT AVAILABILITY: Special Order

COST: U

OPERATING CHARACTERISTICS

TRANSFER FUNCTION: U

FREQUENCY RESPONSE: U TIME RESPONSE: 150 ms

SUPPLY: PRESSURE- .5 to 8 psig FLOW: To 0.75 scfm

OUTPUT: PRESSURE- 2.0 psig @ 8 psig supply

CONTROL VOLTAGE: 1.9 Volts A.C. CONTROL CURRENT: 2.5 Amps

SCALING ABILITY: U

LINEARITY: RANGE: NA ACCURACY: U

SENSING RANGE: 0 - 13 Volts

HYSTERESIS: U GAIN: U

OUTPUT SIGNAL: ΔP across output legs

CROSS SENSITIVITY EFFECTS: U

S/N RATIO: U EXPECTED LIFE: U

MTBF: U MCBF: U MTTR: U

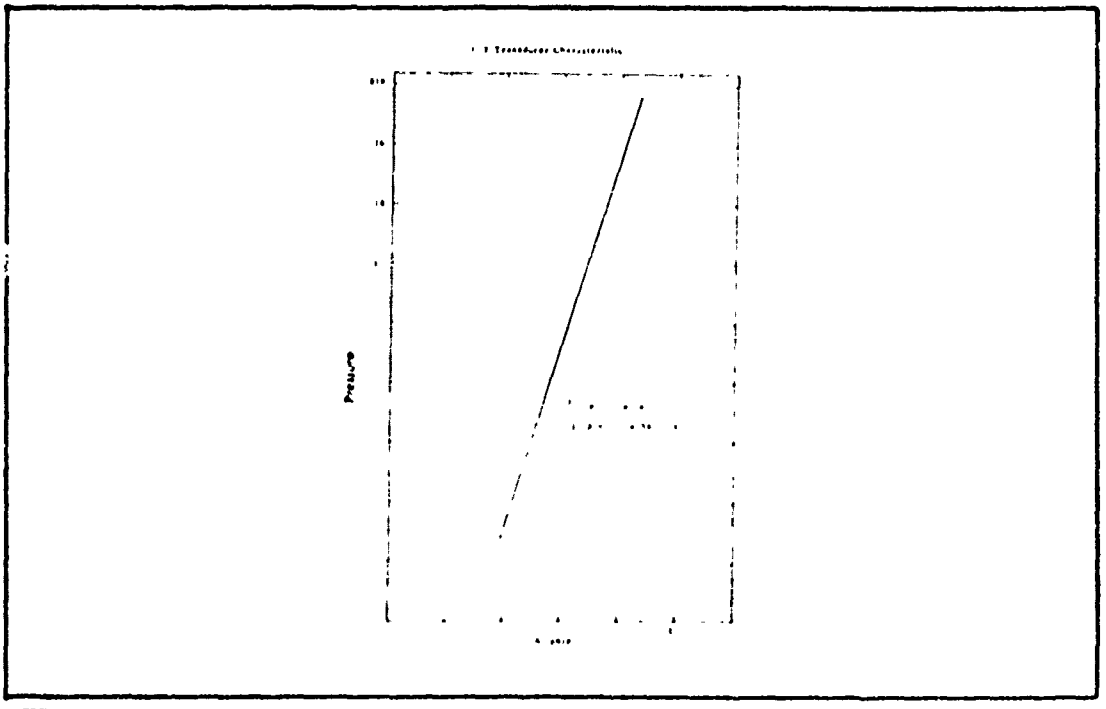


FIGURE 2.140 AVAILABLE DATA: EF TRANSDUCER - EMX ENGINEERING, INC.

3. CONCLUSIONS

Material presented in this state-of-the-art survey was heavily oriented toward providing the basic geometric and operating data required for a design engineer to utilize fluidic technology. Although full cooperation was not received from all organizations who received a copy of the questionnaire, the material presented herein reveals that fluidic sensing technology is indeed state-of-the-art and can be employed in many different types of circuits.

This survey, however, also served a second purpose. It may not be all-inclusive, but it does demonstrate two important results.

- A considerable number of sensors are still basically in the R&D stage, and thus require venture capital and/or IR&D funds to further their development.
- There are a number of areas where new devices are warranted since fluidic sensing offers a promise that has not yet been realized.

With regard to the latter statement, it has been demonstrated that the equipment reliability is much higher with fluidics than with competing electrical or electrical/mechanical elements. Furthermore, their costs have now become competitive, and with the development of new types of elements (or variations of existing elements), accuracies and reliability are constantly being improved.

APPENDIX A

FLUIDIC SENSOR QUESTIONNAIRE

LORELEI CORPORATION

FLUIDIC SENSOR QUESTIONNAIRE

GENERAL INSTRUCTIONS

Most questions presented herein are self explanatory and require nothing more than a check-off in the space provided. However, the detailed instructions are intended to assist you in responding to the following specific items.

Item A.6. Indicate your source of information for filling out this questionnaire.

Item B.1. If available, list the manufacturer's part number. If there is no part number, list as A,B,C,D to provide correlation with questions B.2. and E.4. Also be sure to indicate units (inch, cm, etc.)

Item C.8. If the performance of the sensor changes with scaling (e.g., loss of gain with increase in size) explain and use a separate questionnaire for each size.

Item C.16. Indicate the result of secondary effects on the performance of the sensor (e.g., temperature on an acceleration sensor, pressure on a temperature sensor, etc.)

Items C.19,20,21. Indicate how the reliability figures were obtained and if tests were conducted, what parameters were controlled.

Item D.5. Explain if and how the sensor causes any change in the quantity being measured (e.g., pressure drop, temperature increase, etc.)

If additional space is needed, the form can be copied on standard size paper. Further, if any question is not applicable to your sensor, put (NA) in the appropriate space; and if the answer is unknown, put in a question mark (?). For those items flagged by an asterisk (*) we would appreciate additional information in the form of charts or graphs. Lastly, please attach a photograph (or preferably a cutaway diagram) to the completed questionnaire prior to mailing to: LORELEI Corporation, 615 South Frederick Avenue, Gaithersburg Maryland 20760, Attn:LMS.

Thank you for your interest and co-operation in this program.

A. GENERAL INFORMATION

1. Type of Sensor: _____ 2. Moving Parts: Yes _____ No _____

3. Logic Symbol:

_____

4. Symbol Reference: NFPA _____ Mil-Std-1306A _____ Other _____

5. Principle of Operation: _____

_____

_____

_____

6. Source: Manufacturer _____ Inventor _____ Other _____

7. Primary Fluid: Air _____ Water _____ Other _____

8. Active: _____ Passive: _____ 9. Analog: _____ Digital: _____

10. Interface: Type _____ Provided: Yes _____ No _____

11. Readout: Provided _____ Required _____ If Reqd, Describe _____

_____

12. List Typical Applications: _____

_____

_____

B. GEOMETRIC PROPERTIES

1. Iden# _____ Size _____ Hgt _____ Wdth _____ Lgth _____ Wt _____

Iden# _____ Size _____ Hgt _____ Wdth _____ Lgth _____ Wt _____

Iden# _____ Size _____ Hgt _____ Wdth _____ Lgth _____ Wt _____

Iden# _____ Size _____ Hgt _____ Wdth _____ Lgth _____ Wt _____

2. Connectors:

Iden# _____ Input: Type _____ Size _____

Output: Type _____ Size _____

Iden# _____ Input: Type _____ Size _____

Output: Type _____ Size _____

Iden# _____ Input: Type _____ Size _____

Output: Type _____ Size _____

Iden# _____ Input: Type _____ Size _____

Output: Type _____ Size _____

3. Installation Provisions/Precautions: _____

_____

4. Construction: Type _____ Material _____

5. Other Pertinent Data: _____

C. OPERATING CHARACTERISTICS

1. Transfer Function: _____

_____

2. Frequency Response: _____ Hz 3. Time Response: _____

4. Supply: Pressure-Minimum _____ Maximum _____ (*)

Flow-Minimum _____ Maximum _____ (*)

Power-Minimum _____ Maximum _____ (*)

5. Output: Pressure-Minimum _____ Maximum _____ (*)

Flow-Minimum _____ Maximum _____ (*)

Power-Minimum _____ Maximum _____ (*)

6. Control: Pressure-Minimum _____ Maximum _____ (*)

Flow-Minimum _____ Maximum _____ (*)

Power-Minimum _____ Maximum _____ (*)

7. Impedance: (*) Input _____ Output _____

8. Scaling Ability: Yes _____ No _____ Explain _____

_____

_____

9. Linearity: (*) Range _____ Accuracy _____

10. Total Range: Threshold _____ Accuracy _____

Saturation _____ Accuracy _____

11. Define Accuracy: _____

_____

_____

12. Hysterisis: (*) _____ 13. Gain: (*) _____

14. Output Signal: AC _____ DC _____ 15. Null Point: _____

16. Cross Sensitivity Effects: _____

_____

_____

17. S/N Ratio: _____ 18. Expected Life: _____

19. MTBF: _____ Estimated _____ Tested _____ Parameters _____

_____

20. MCBF: _____ Estimated _____ Tested _____ Parameters _____

_____

21. MTTR: _____ Estimated _____ Tested _____ Parameters _____

_____

22. Indicate Unusual Characteristics: _____

_____

D. ENVIRONMENTAL LIMITATIONS

1.Temperature: High_____ Low_____ 2.Humidity:_____
3.Pressure:_____(or Altitude)_____
4.Power Supply Filtration: Yes_____ No_____Explain_____
_____
5.Effect on Measured Quantity:(*) Yes_____ No_____ Explain_____
_____
6.Acceleration Sensitive: Yes_____ No_____ Unknown_____
If Yes,Explain_____
7.Noise Sensitive: Yes_____ No_____ Unknown_____
If Yes,Explain_____
8.Shock Sensitive: Yes_____ No_____ Unknown_____
If Yes,Explain_____
9.Vibration Sensitive: Yes_____ No_____ Unknown_____
If Yes Explain_____
10.Reference: Ambient-Yes_____ No_____ Other-Yes_____ No_____
If Other Explain_____
11.Tested per Mil Spec Requirements: Yes_____ No_____ Explain_____
_____
_____
_____

E. ORDERING INFORMATION

1.Manufacturer or Source: Name_____
Street_____
City_____State_____Zip_____
2.Point of Contact:Name_____Code_____Phone_____
3.Product Availability: Off-the-Shelf_____ Laboratory Item_____
4.Cost: Estimated_____ Current Price Sheet Attached_____
Iden#_____ Unit $_____ Bulk (Quantity) $_____(_____)
Iden#_____ Unit $_____ Bulk (Quantity) $_____(_____)
Iden#_____ Unit $_____ Bulk (Quantity) $_____(_____)
Iden#_____ Unit $_____ Bulk (Quantity) $_____(_____)
5.Average Delivery Time:_____ 6.Special Order: Yes_____ No_____
7.Special Order Available: Yes_____ No_____Details_____
_____
Questionnaire Prepared By:_____Phone_____Date_____

APPENDIX B

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